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SPACE SHUTTLE PHASE B
STUDY PLAN

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Prepared by

Program Administration

B. Hello
Vice President and
General Manager
Space Shuttle Program

Space Division
North American Rockwell

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ILLUSTRATIONS

INTRODUCTION

This Space Shuttle Phase B Study Plan has been prepared in accordance with DRD MA 080M (DRD Line Item 1). The study plan shows the functional and time-phased flow of tasks and subtasks, the manpower planned for each task, proposed subcontracts and key milestones. In order to provide greater visibility to NASA, the task statements reflect the planned utilization of data resulting from company-sponsored activities. The plan will be used as a guide in performance of the contract requirements.

The main body of this plan is divided into seven sections. The first section presents the management and engineering organizations that will accomplish the technical effort, brief descriptions of key personnel functions, and the subcontractor plan. The second section contains the Phase B Work Breakdown Structure (WBS), which correlates directly to the program management network and master program schedule; the third section includes the task descriptions for each WBS element; and the fourth section, the time-phased manpower summary for each WBS element. The fifth section presents the Space Shuttle master program schedule and program management network. The sixth section identifies the Government-furnished documentation required from NASA to support the Phase B study contract, and the seventh section describes the management techniques that will be utilized to provide management visibility and control of the study effort.

The approved Study Plan will be used by NR as a guide in performing the Phase B contract effort. The plan will be revised, as required, during the course of the study to reflect any major redirection by NASA or major replanning by NR. Such revisions will be coordinated with the NASA Technical Manager prior to distribution of the revised plan.

1.0 PHASE B ORGANIZATION

This section presents the primary organizations, key personnel functions, and the subcontractor plan to be used by NR in accomplishing the Space Shuttle Definition study contract.

1.1 PRIMARY ORGANIZATIONS

The total Space Shuttle Program organization for Phase B is shown on Figure 1-1. The Convair program organization is shown on Figure 1-2. The NR and GD engineering organizations are shown on Figures 1-3 and 1-4. The IBM, American Airlines, and Honeywell organizational structures are shown on Figures 1-5, 1-6, and 1-7.

1.2 SUBCONTRACT PLAN

This section contains the plan for major subcontractors selected to support Space Division and its associate contractor, Convair, during the Phase B study. The subcontractors selected are American Airlines, Honeywell, and IBM. Subcontractor tasks are included, along with Space Division and Convair effort, in the Task Description section of the Study Plan but are identified here in greater detail.

Figure 1-8 presents the key subcontractor milestones and time-phased manpower. The area and scope of responsibility for each subcontractor is presented in the following paragraphs.

1.2.1 American Airlines

American Airlines (AAL) will be responsible for providing support to Space Division and Convair for the following Phase B study requirements: maintainability, maintenance and logistics; ground facilities, operations and equipment; passenger and cargo handling; and quality and reliability. AAL will perform the following tasks: Provide design criteria for accessiblity, inspection and checkout techniques, replacement for minimum down-time, effect of launch site environment, and unscheduled maintenance; prepare a syllabus and conduct maintainability orientation training course for Space Division/Convair team personnel; provide data on sparing and logistics philosophy, procedures and planning related to commercial aircraft, and analysis application to the Space Shuttle Program; modify the present AAL Project Management System (PMS) program model for commercial aircraft to provide critical path method (CPM) of maintenance for orbiter and booster;

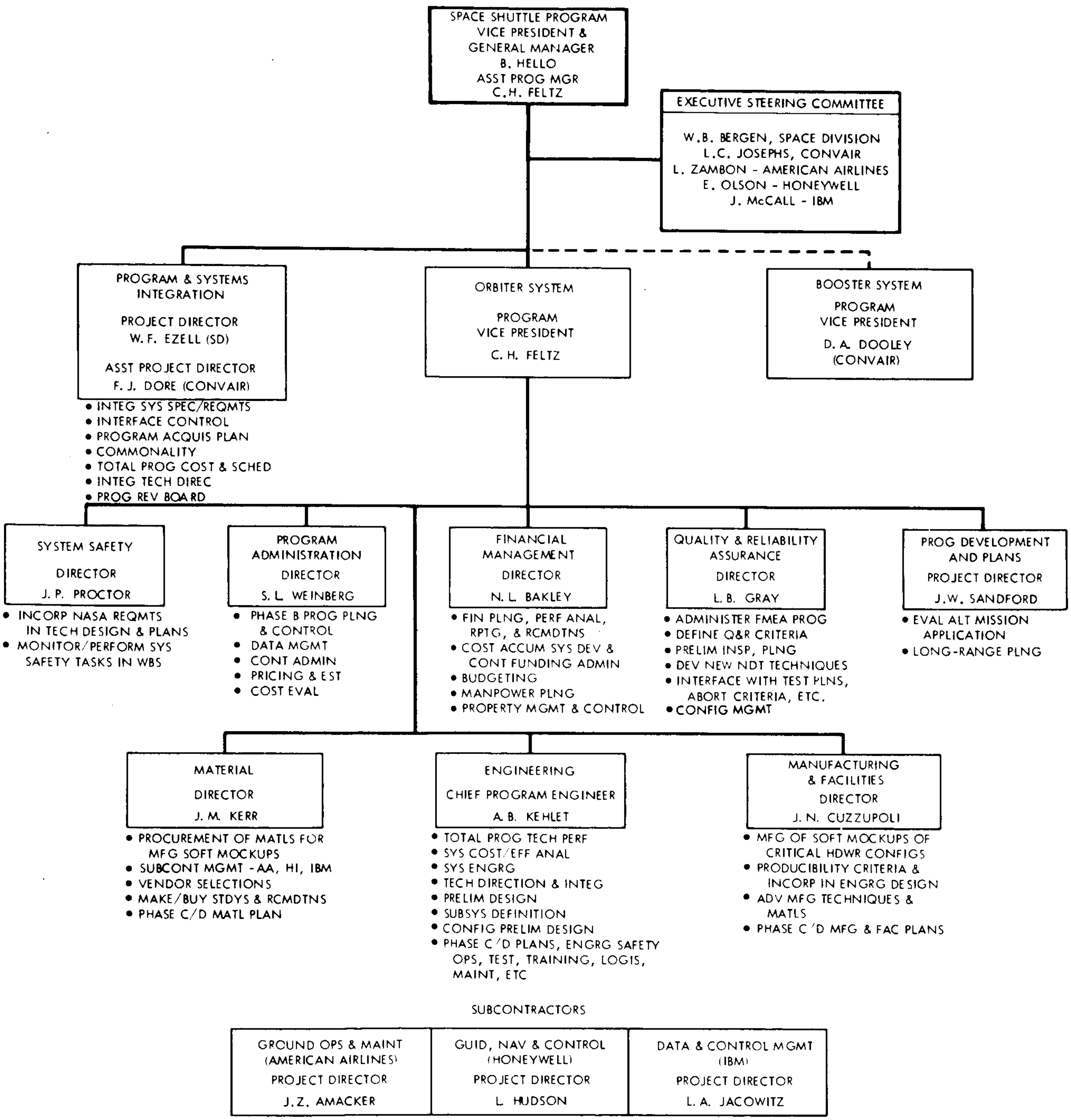


Figure 1-1. Space Shuttle Program Organization

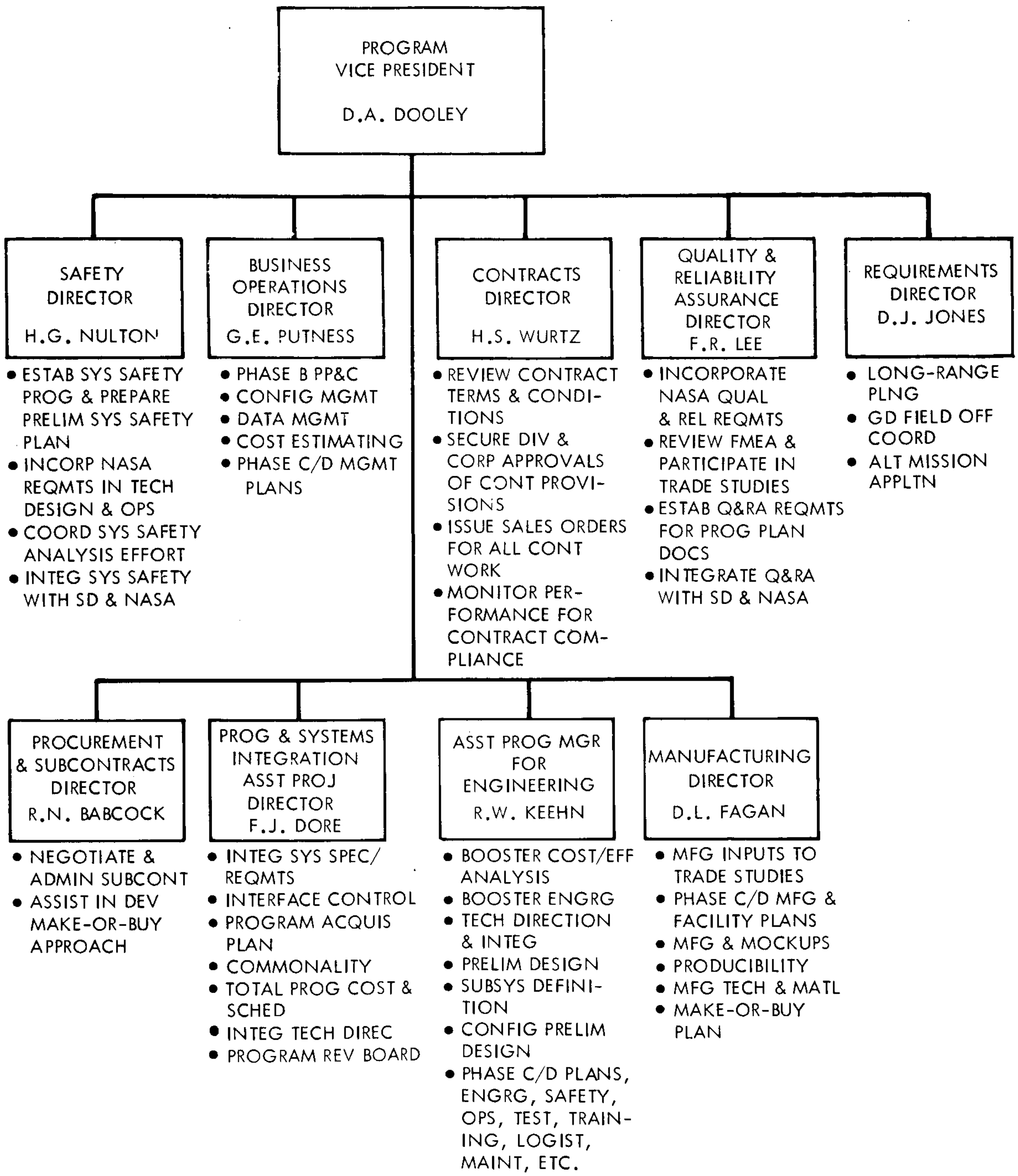


Figure 1-2. Convair Space Shuttle Program Organization

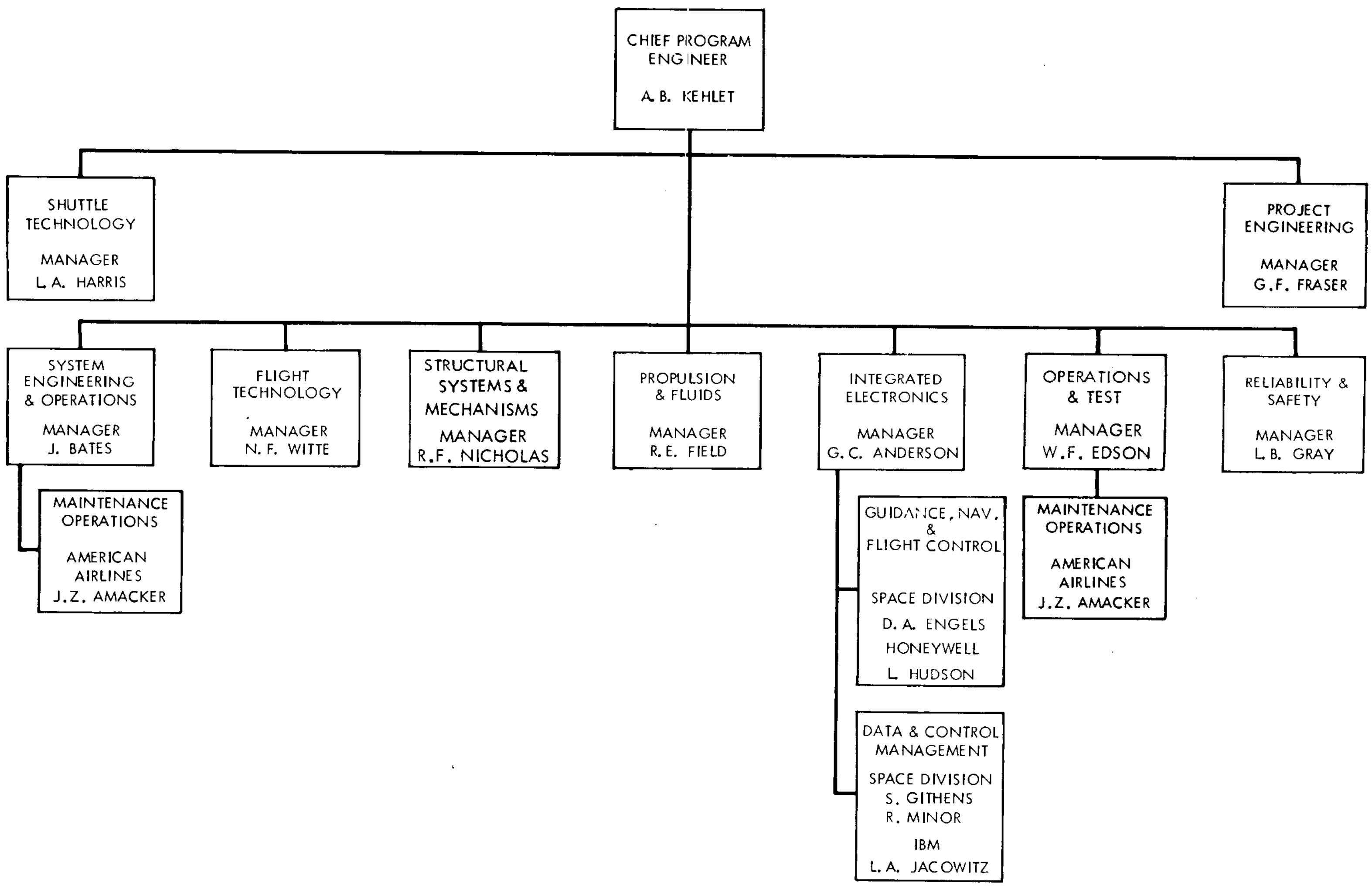


Figure 1-3. Space Division Space Shuttle Engineering Organization

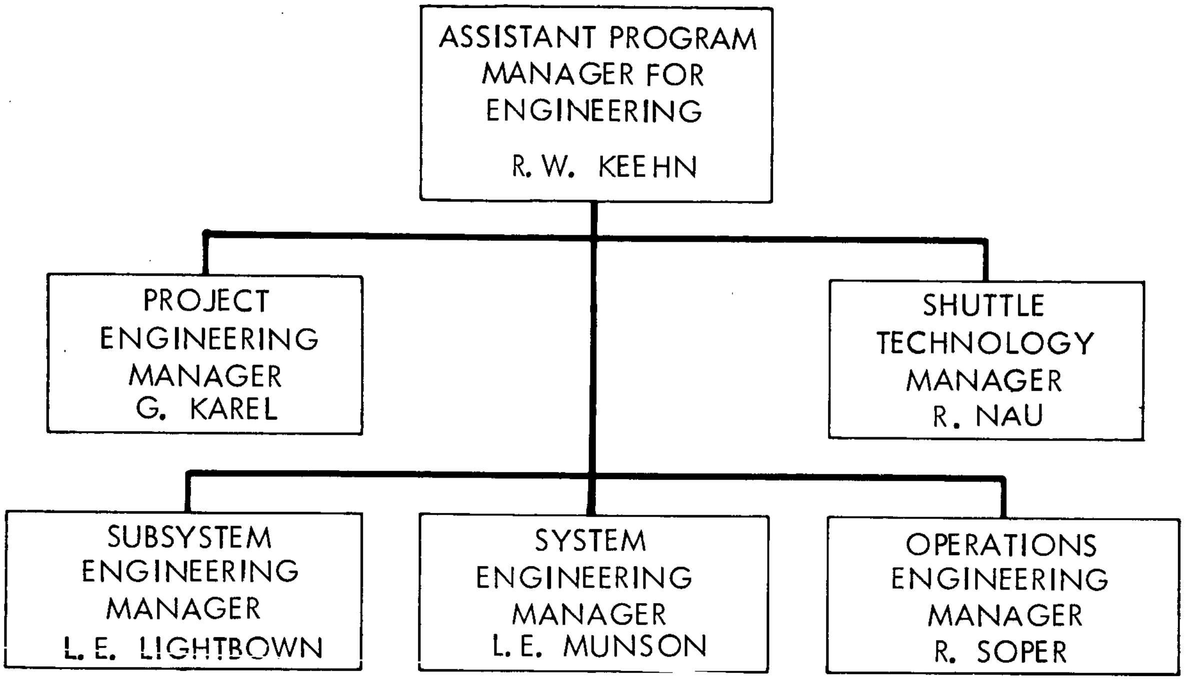


Figure 1-4. Convair Space Shuttle Engineering Organization

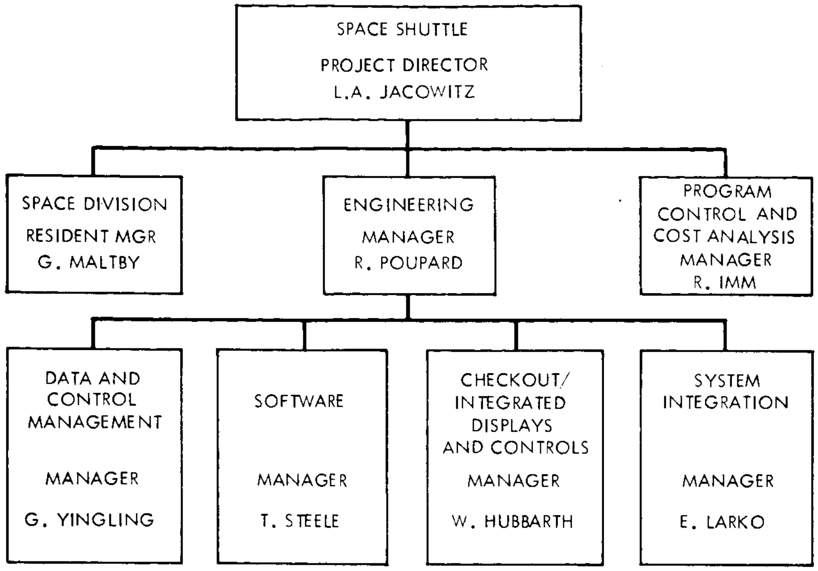


Figure 1-5. IBM Space Shuttle Organization

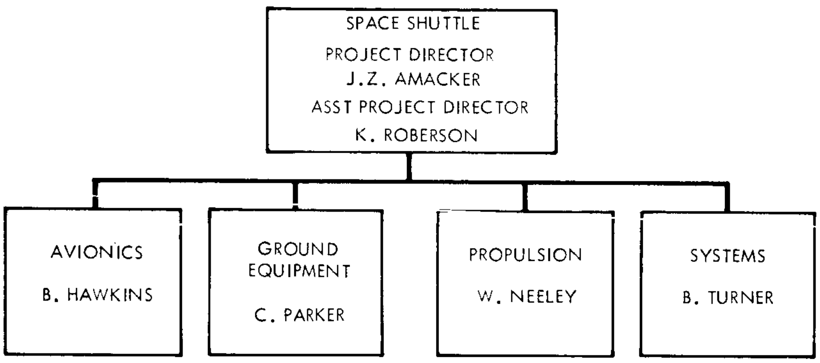


Figure 1-6. American Airlines Space Shuttle Organization

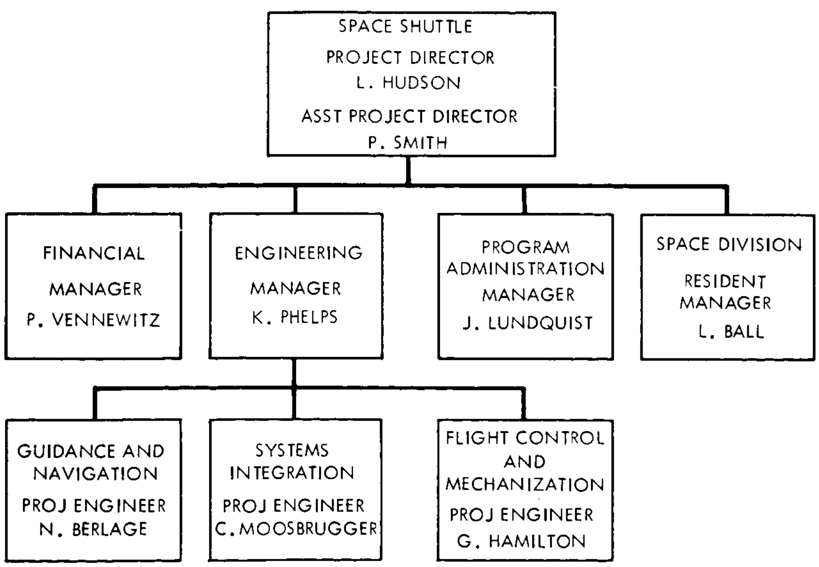


Figure 1-7. Honeywell Space Shuttle Organization

SUBCONTRACTOR	MONTHS AFTER GO-AHEAD												
	Milestones	1	2	3	4	5	6	7	8	9	10	11	12	TOTAL
AMERICAN AIRLINES	START ESTABLISH DESIGN CRITERIA FOR MAINTAINABILITY PRESENT MAINTAINABILITY ORIENTATION COURSE COMPLETE MAINTAINABILITY DESIGN HANDBOOK MAINTENANCE FACILITY REQUIREMENTS INPUT MAINTENANCE MODEL COMPUTER OUTPUT SUPPORT TO FINAL REPORT COMPLETE													
EQUIVALENT MAN-MONTHS		1.7	2.3	2.7	3.1	3.5	3.5	3.3	2.4	1.8	1.8	1.4	0.9	28.4
HONEYWELL	START ESTABLISH RELIABILITY REDUNDANCY IMPLEMENTATION TECHNIQUE GUIDANCE DEFINITION FLIGHT CONTROL DEFINITION DISPLAY & CONTROLS REQUIREMENTS DEFINED COMPLETE GUIDANCE & NAVIGATION BLOCK DIAGRAMS SUBMIT FINAL REPORT DATA SUPPORT TO FINAL REPORT COMPLETE													
EQUIVALENT MAN-MONTHS		15.0	22.0	24.0	25.6	24.6	22.6	17.7	10.0	7.1	6.1	3.8	0.5	179.0
IBM	START UNMANNED VERSUS MANNED BOOSTER TRADE STUDY INPUT ELECTRONIC GROUND EQUIPMENT DEFINITION UPDATE FMEA'S COMPLETE SOFTWARE DEVELOPMENT COMPLETE SUBMIT FINAL REPORT DATA SUPPORT TO FINAL REPORT COMPLETE													
EQUIVALENT MAN-MONTHS		12.0	15.0	17.0	20.0	21.0	21.0	22.0	32.0	9.1	5.5	5.5	0.5	180.6

Figure 1-8. Subcontractor Milestones and Manpower

provide assistance in preparing a level-of-repair decision model (data elements include time allowed off vehicle, elapsed repair time, pipeline time, frequency of repair, personnel classifications and quantities, and facility and repair equipment costs); assist in identification of specific space shuttle maintenance facility and ground support equipment requirements for the primary landing site (same as launch site) and alternate landing sites for operational missions; assist in identification of crew and passenger accommodations for the space shuttle system; assist in identification of requirements for cargo handling, loading, and unloading; and assist in determining quality assurance and reliability criteria and requirements for the space shuttle system from vehicle acceptance through the operational phase.

1.2.2 Honeywell, Inc.

Honeywell will be responsible for guidance, navigation, and flight control within the integrated avionics system. This includes the following significant elements: inertial measurement sensors, flight control processor, guidance policies, actuator drive electronics, and dedicated pilot displays and controls.

Honeywell will perform the following tasks: Requirements analysis, concepts definition and evaluation; configuration analysis, preliminary design, and design and development planning; and program cost and schedule estimates.

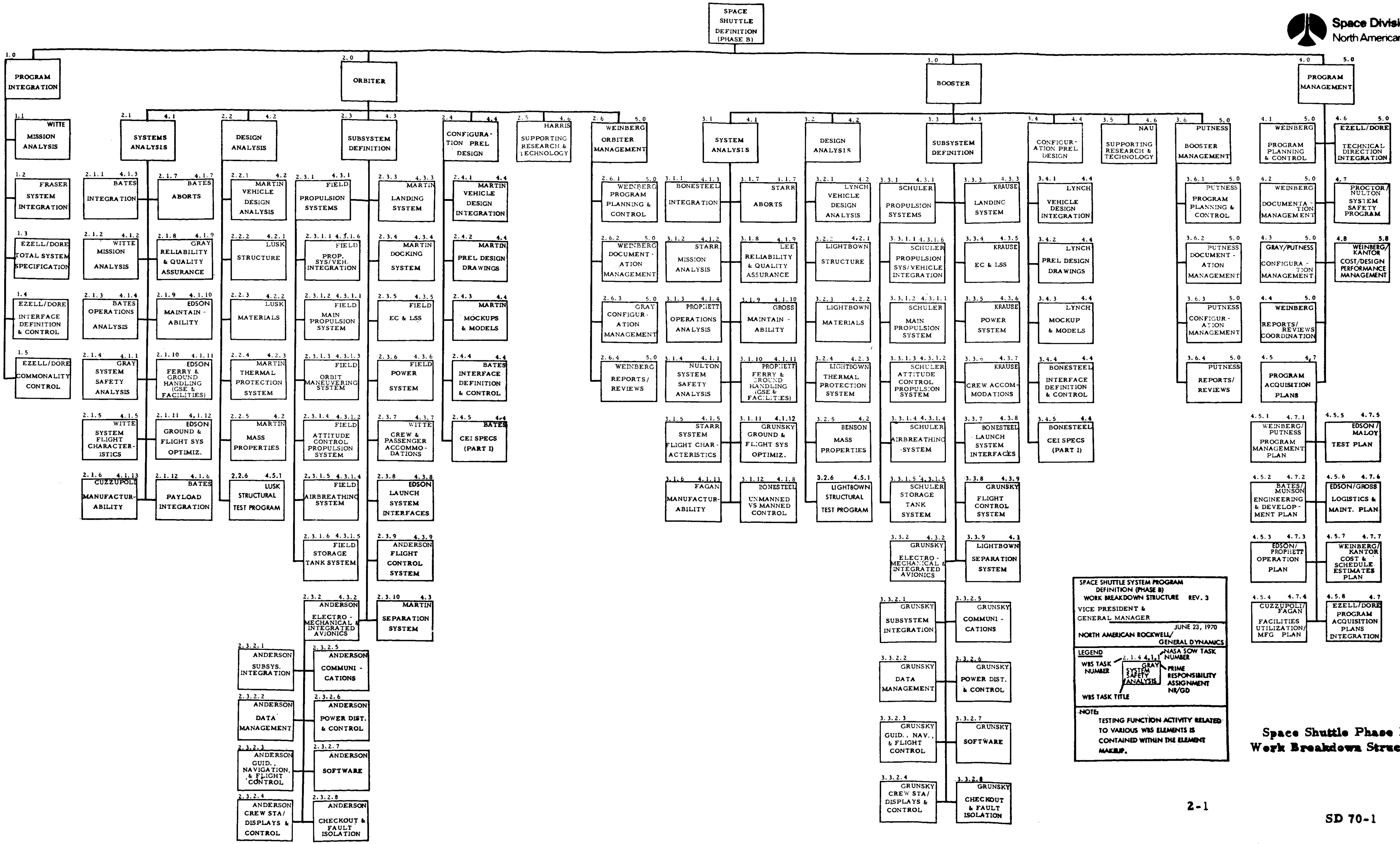
The most significant trade studies, which will be documented by Kepner-Tregoe-type matrices and supporting data, are gimbaled versus strapped-down inertial measurement unit (IMU); nonresident/central versus resident/dedicated GN&C computer; degree of GN&C autonomy; evaluation of the degree of pilot routine participation in baseline GN&C functions, load relief during boost versus trajectory accuracy, automatic versus manual docking/rendezvous control, automatic landing system definition and implementation, ILS versus automatic ground controlled approach (GCA); star tracker/horizon sensor versus other optical sensors (e.g., manual versus automatic sextant for GN&C initialization and calibration); strapdown algorithm mechanization; reliability/redundancy implementation; automatic inertial versus ground aided navigation; adaptive control versus gain scheduling or fixed gain for boost, entry, and aerodynamic flight; powered versus unpowered landing requirements; and air data versus no air data sensors.

1.2.3 IBM

IBM will be responsible for data and control management (DCM), integrated displays and controls (ID&C), and checkout and fault isolation functions (COFI), which include the following elements and functions of the onboard booster and orbiter integrated avionics system: computer configuration and data processing; control interfaces with onboard and external equipment; integrated displays and controls, data and control bus, checkout and fault isolation; and computer software. Ground-based electronic elements and functions include centralized data processing; checkout and support equipment interfaces; software; and mission control interfaces with DCM.

IBM will perform the following tasks: requirements analysis, parametric studies, concepts definition and evaluation, configuration analysis and preliminary design, preparation of software specifications, design and development planning, and program cost and schedule estimates.

The most significant trade studies, which will be documented by Kepner-Tregoe-type matrices and supporting data, are (1) data control management, which includes centralized versus decentralized computer concepts and standard versus multiplexed data acquisition and control concepts, with emphasis, on flexibility and electromagnetic compatibility; (2) integrated display and control studies, which include configuration/ methodology, integrated (i. e., time or space-shared) versus dedicated (individual) display/control organization, and analog (graphic/pictorial) versus digital (alphanumeric) modes of information presentation, hardware/ technology, electro-optical versus electronic multipurpose displays, and electronic versus electromechanical mechanization of discrete controls; (3) checkout and fault isolation studies, which include onboard versus ground checkout and fault isolation trade study, centralized versus decentralized checkout and control, checkout participation in the redundant mode selection trade study, and automated decision making versus crew selection of operational mode; and (4) booster/orbiter commonality (DCM, ID&C, and COFI subsystems).



Space Shuttle Phase B Work Breakdown Structure

TASK DESCRIPTION INDEX

SPACE SHUTTLE PHASE B
TASK DESCRIPTIONS

WBS TITLE: MISSION ANALYSIS

WBS Number: 1.1
Integration Tasks

Company:	Function:	Manager:
NR	Flight Technology	N. F. Witte

Define flight trajectories, determine performance sensitivities to mission and design changes and conduct or support trade studies for the ascent flight phase.

1. Provide ascent trajectory and dispersion data as required for system design.

2. Develop and document ascent performance sensitivities to determine optimum staging conditions relative to mission requirements changes and design alternatives.

3. Provide trajectory and dispersions data as required for ascent control system design.

4. Evaluate and document the results of the following company sponsored studies for application to the contract effort:

   a. Conduct the trade study Vehicle Propellant Distribution and Main Propulsion Sizing to determine the optimum integrated vehicle configurations. Consider T/W, number of engines, Isp (O/F, ,) loads, staging conditions, injection conditions, and abort requirements.

   b. Conduct a parametric analysis of lifting ascent trajectories to determine desirability for the SSV.

   c. Formulate and incorporate modifications to the NR ascent flight simulation digital computer programs to improve capabilities for parametric evaluation of optimum atmospheric ascent performance.

WBS Number: 1.1
Integration Tasks (Cont)

d. Provide ascent performance data and vehicle design change requirements in support of the "vehicle alternate missions capability" trade study.

WBS Number: 1.1
Orbiter Tasks

Company:	Function:	Manager:
NR	Project Engineering	G. Fraser

1. Establish ground rules for Mission Analysis trade studies, Vehicle Propellant Distribution and Main Propulsion Sizing and Vehicle Alternate Mission Capability.

2. Review trade studies approach and subtasks to:

   a. Ensure that the selected propellant distribution, number of engines, thrust level, expansion ratio, and mixture ratio for the main rocket engine will accomplish the Space Shuttle mission in the most efficient manner.

   b. Ensure that the impact of performing alternate missions are established. Coordinate activities to select missions which will be performed by shuttle. Ensure shuttle is designed to provide capability to perform selected missions.

3. Coordinate presentation of trade study results and recommendations to the ERB.

4. Ensure results of Mission Analysis trades are presented to NASA.

5. Coordinate mission analysis activity in support of System Integration (WBS 1.2) tasks to incorporate study results into an updated baseline.

SPACE SHUTTLE PHASE B
TASK DESCRIPTIONS

WBS TITLE: SYSTEM INTEGRATION

WBS Number: 1.2
Integration Tasks

Company:	Function:	Manager:
NR	Project Engineering	G. F. Fraser

1. Define tasks, data requirements, and schedule for system and vehicle integration and incorporation of trade and design study results into the space shuttle system. The activities in support of system integration are summarized below with references to detail task definitions in other elements of the WBS.

   a. Identification of mission/system requirements (Ref. 1.3 and 2.1.1).

   b. Definition of system integration procedures (Ref. 2.1.1).

   c. Identification of vehicle performance and design interface requirements (Ref. 1.3, 1.4, 1.5, and 2.4.4 and 3.4.4).

   d. Definition of vehicle configuration (Ref. 2.2.2, 4.3.2 and 3.4).

   e. Definition of vehicle performance capability (Ref. 1.1, 2.1.2, 2.1.5, 3.1.2 and 3.1.5).

   g. Definition of subsystems (Ref. 2.3 and 3.3).

   h. Identification of ground and flight operational requirements (Ref. 2.1.3 and 3.1.3).

   i. Definition of ground and flight operations (Ref. 2.1.3 and 3.1.3).

   j. Definition of ground system facilities and equipment (Ref. 2.1.10, 2.3.8, 3.3.8 and 3.1.10).

   k. Development of resource plans - design, test, manufacture (Ref. 4.5).

WBS Number: 1.2
Integration Tasks (Cont)

l. Estimation of system costs (Ref. 4.5.7).

m. Generation of development schedule (Ref. 4.5.7).

Manpower allocations for tasks a through m are identified against orbiter and booster analyses.

2. Integrate vehicle systems definitions derived in accordance with the following study phases:

Vehicle Configuration Trades	0- 2 months
Initial Integrated Baseline Vehicle Definition	2- 3 months
Subsystem Concept and Operations Trades	3- 5 months
Interim Baseline Vehicle Definition	5- 6 months
Preliminary Design	6-11 months

The vehicle integration will be performed as follows:

a. Generation of vehicle ground rules, criteria, scaling data.

b. Computerized vehicle synthesis to define sizes; analysis to define mass properties.

c. Preparation of orbiter and booster layouts.

d. Definition of orbiter, booster, and integrated vehicle aerodynamic characteristics.

e. Definition of trajectories.

f. Control system optimization.

g. Definition of structural model.

h. Definition of loads.

i. Definition of thermal environment.

j. Definition of structure/TPS.

k. Vehicle definition (configuration, subsystem, weight).

l. Final vehicle performance.

WBS Number: 1.2
Integration Tasks (Cont)

3. Prepare integration directive including summary of trade decisions; vehicle arrangement (integrated system), booster and orbiter shape, TPS concepts, structural features; number of engines, expansion ratio, mixture ratio for main engine system and OMS system and airbreathing engines as applicable; weight scaling data; combined vehicle drag; design wind profiles; booster and orbiter main engine OMS (for orbiter) data, Isp, weight, size, pressure schedule, percent residuals, ullage, losses, system weight factor; orbiter and booster air breather engine types, SFC, weights, size, residuals, landing speed criteria, control system parameters. Prepare similar package for integrated vehicle update, including subsystem trades design concepts.

4. Maintain baseline vehicle definition summary.

5. Identify vehicle/system integration decisions to be made by the ERB meetings, and release ERB decisions/direction.

6. Coordinate systems trade studies involving more than one functional area through coordination with GD, direction of technology panels and coordination between functional groups. Ensure compatibility between orbiter and booster operation, performance and subsystem design. Coordinate system integration task to obtain shuttle system which meets systems and subsystems requirements in logical and economic fashion.

7. Review system integration data with NASA and ensure completion of documentation and reporting of results to NASA.

   Mated vehicle analysis and design tasks in support of vehicle integration are described below for reference and are repeated in the referenced WBS description. Analysis and design tasks (in support of vehicle integration) of the separated orbiter and booster are given in appropriate sections of the WBS under orbiter and booster tasks.

8. Perform shuttle vehicle synthesis to establish (1) propellant distribution, (2) gross vehicle weight distribution, (3) gross booster and orbiter sizes, (4) vehicle pitch plane point mass trajectory, and (5) vehicle ascent q history. Conduct sensitivity analysis to weight, Isp and system changes. Establish payload capability using precision flight performance program and compare trajectory with that developed during vehicle synthesis. (Ref. 1.1).

WBS Number: 1.2
Integration Tasks (Cont)

9. Prepare integrated vehicle aerodynamic derivatives. Prepare integrated vehicle aerodynamic force distribution for prelaunch, ascent max q , and ascent max g (Ref. 2.1.5).

Company:	Function:	Manager:
NR	Flight Technology	N. F. Witte

10. Establish integrated vehicle q versus time and location during ascent (Ref. 2.2.4).

Company:	Function:	Manager:
NR	Preliminary Design	W. Martin

11. Prepare integrated vehicle layouts showing general arrangement and dimensions. Update layouts as required. (Ref. 2.2.1 and 2.4.2).

12. Prepare mass properties descriptions for integrated vehicle including weight, area, and volume statement; weight distribution; and pitch, yaw, and roll plane inertia (Ref. 2.2.5).

Company:	Function:	Manager:
NR	Vehicle Structures	R. A. Lusk

13. Perform loads analysis at critical flight conditions for mated configurations (Ref. 2.2.2).

Company:	Function:	Manager:
NR (HI)	Integration Avionics	G. Anderson (L. Hudson)

14. Perform initial rigid body pitch plane flight control analysis for mated configuration to determine optimum steering program based on loads and performance. Include definition of design loads and heating trajectories in analysis. For final analysis, include bending and slosh in control system analysis. (Ref. 2.3.2).

WBS Number: 1.2
Integration Tasks (Cont)

Company:	Function:	Manager:
NR	Fluids and Propulsion	R. E. Field

15. Furnish descriptions and data on alternate approaches to design of power, propulsion, ECLS, systems to include functional descriptions, operating characteristics, interfaces with other systems, size and weight characteristics for individual elements, and preferred location of individual elements, accessibility requirements, and environmental restrictions.

SPACE SHUTTLE PHASE B
TASK DESCRIPTIONS

WBS TITLE: TOTAL SYSTEM SPECIFICATION

WBS Number: 1.3
Integration Tasks

Company:	Function:	Manager:
NR	Program and System Integration	W. F. Ezell

1. Establish definition, requirements, and guidelines for preparation of top system specification.

2. Schedule baseline and final documentation submittal.

3. Conduct periodic reviews, both in-house and with NASA, to control and assure definition of the technical and mission requirements for the shuttle system as an entity, allocation of requirements to functional areas, and definition of interfaces between or among functional areas.

4. Review for and recommend approval to the program manager of the baseline system specification and changes thereto, using Program Review Board processes.

Company:	Function:	Manager:
NR	System Engineering	J. Bates

5. Prepare the shuttle system specification per MIL-STD-490.

6. Analyze NASA documents and mission-and-operations (functional analysis) outputs to develop rationale for system requirements.

7. Prepare preliminary system specification for use during Phase B study as an internally controlled system requirements document.

8. Maintain preliminary system specification, incorporating changes resulting from ERB action and issuing block change update, prior to NASA reviews.

WBS Number: 1.3
Integration Tasks (Cont)

9. Coordinate above changes to ensure continuity between system CEI Part I specifications and other non-CEI specification and interface control documents.

10. Participate in NASA review of the specification and revise as required.

Company:	Function:	Manager:
GD	Program and System Integration	F. J. Dore

11. Assist NR in accomplishing integration per above functions.

SPACE SHUTTLE PHASE B
TASK DESCRIPTIONS

WBS TITLE: INTERFACE DEFINITION AND CONTROL

WBS Number: 1.4
Integration Tasks

Company:	Function:	Manager:
NR	Program and System Integration	W. F. Ezell

1. Establish documentation required and preparation responsibility for interface control drawings necessary to define significant functional and physical interfaces required to make the shuttle system compatible with other systems and to make its end items compatible within the system.

2. Schedule baseline and final documentation submittal.

3. Schedule periodic reviews, both in-house and with NASA, to control and assure that the interface control drawings are input and output oriented with a focus on conditions at equipment interfaces and do not contain characteristics of equipment which are used in subsystem or system analysis.

4. Review for and recommend approval to the program manager of baseline ICD's and changes thereto, using Program Review Board processes.

Company:	Function:	Manager:
NR	System Engineering	J. Bates

5. Establish the format for and coordinate the preparation of interface control documents to be submitted during the shuttle system Phase B study.

6. In conjunction with preparation of the system specification, define major interfaces between shuttle system functional areas.

WBS Number: 1.4
Integration Tasks (Cont)

7. Review Apollo, Saturn, and GDC interface control practices and formats to develop policy and format for shuttle system interface control; make recommendations in this regard.

8. Analyze shuttle specifications to assist in definition of physical, functional, and procedural interface requirements for all system elements.

9. Plan, schedule, and coordinate the engineering activities to ensure preparation of the defined ICD's; review and approve engineering draft of ICD's for submittal to ERB (Ref. 2.4.4 and 3.4.4).

10. Participate in NASA review of ICD's and coordinate revisions as required.

Company:	Function:	Manager:
GD	Program and System Integration	F. J. Dore

11. Assist NR in accomplishing integration per above functions.

SPACE SHUTTLE PHASE B
TASK DESCRIPTIONS

WBS TITLE: COMMONALITY CONTROL

WBS Number: 1.5
Integration Tasks

Company:	Function:	Manager:
NR	Program and System Integration	W. Ezell

1. Define a plan to assure identification and assessment of a candidate list of common items which embrace the total shuttle program and which permit practical realization of the objective of reduced over-all program costs through commonality.

2. Develop guidelines for use of commonality candidates in Phase C and D documentation generated in Phase B.

3. Accomplish joint SD and Convair reviews of individual subsystems to establish a commonality candidate list.

4. Assure that validation of the commonality candidate list is accomplished through the planned trade study, design analysis, and program planning tasks.

5. Review and control changes to the commonality candidate list; present significant changes to the PRB.

6. Assure that commonality decisions are incorporated in the appropriate Phase C and D documents.

7. Coordinate the commonality list with NASA at the major scheduled program reviews.

WBS Number: 1.5
Integration Tasks (Cont)

Company:	Function:	Manager:
NR	System Engineering	J. Bates

8. Assess subsystems and equipment to identify technically feasible commonality candidates.

9. Evaluate subsystem trade study plans and results to assure proper consideration of commonality within the study activity.

10. Lead engineering effort to validate the technical feasibility of commonality items.

11. Maintain and issue as required the commonality control list, including proper status of the various candidates. Assure that ERB actions affecting the status of commonality candidates are reflected in the control list.

12. Support PSI in presentation of commonality status/decision at PRB and program reviews.

13. Assist in defining total implications of commonality so that maximum advantages can be realized through integrated planning for Phases C and D.

Company:	Function:	Manager:
GD	Program and System Integration	F. Dore

14. Assist NR in accomplishing integration per above functions.

SPACE SHUTTLE PHASE B
TASKS DESCRIPTIONS

WBS TITLE: INTEGRATION

WBS Number: 2.1.1
Integration Tasks

Company:	Function:	Manager:
NR	System Engineering	J. Bates

1. Develop a standardized methodology for evaluating trade studies by initial use of a checklist to assist in selecting significant evaluation parameters for preparing trade study plans. This is intended to provide a high degree of consistency among trade studies.

2. Provide support for trade study planning to identify interdependence among study activities and assist in scoping study efforts to minimize repetitive tasks.

3. Evaluate engineering system trade study results and maintain traceability of trade studies through a log of trade studies, study control worksheets, and an over-all trade study schedule. Document ERB trade study decisions, and verify implementation in the design. Maintain a summary description and a history of baseline changes resulting from trade studies, together with cost data summaries during Phase B; and disseminate such data as required.

4. Analyze and expand functional analysis as necessary to define and document system requirements and develop specification tree in support of WBS 1.3 and to allocate requirements to orbiter, booster, and other system elements.

5. Prepare top level schematic block diagrams (SBD's) interrelating the space vehicle, other major system elements, and the space station. Prepare a first level SBD interrelating the orbiter and booster, and coordinate preparation of subsystem SBD's. (Ref. 1.2).

WBS Number: 2.1.1
Integration Tasks (Cont)

6. Analyze above documents to define physical, functional, and procedural interfaces between major elements of the shuttle system. Coordinate this data with WBS 1.5, 2.4.4, and 3.4.4 to develop interface documentation and interface control.

7. Prepare and maintain the Space Shuttle Master Measurement and Control Requirements Document.

8. Establish format for and coordinate preparation of the Shuttle System Definition Handbook (SDH) in accordance with DRD SE004M, to display criteria, requirements, current baseline configurations, and operational concepts. Develop control methods, maintain, and control the SDH; revise and submit for review when baseline block changes are made. (Ref. 1.2).

9. Coordinate preparation of and prepare the system engineering portion of the Part II of the Phase B final report (technical summary) in accordance with DRD MA016M.

10. Coordinate the preparation of technical program plans with the shuttle engineering departments.

Company:	Function:	Manager:
NR	Test Requirements	J. Bates

11. The test integration task includes determination of test requirements (including demonstration of turnaround capability). The test requirements are to be based on definitions of design and performance requirements, mission objectives, and program plans. This consists of the following:

    a. Defining the development test requirements, qualification and reliability test requirements, and acceptance test requirements.

    b. Integrating the development, qualification, and acceptance test requirements (including R&QA test requirements) into the test network.

WBS Number: 2.1.1
Integration Tasks (Cont)

c. Delineating vendor programs for development, qualification, reliability, and acceptance tests of vendor supplied items.

d. Delineating the program requirements for preinstallation tests of replaceable units, including spares.

e. Describing R&QA participation in testing, evaluation, and assessment.

12. Develop Test Program Networks which consist of:

a. Compiling mission mode environments.

b. Compiling system performance requirements.

c. Identifying critical parameter limits and environments versus operational vehicle hardware.

d. Coordinating development test network.

e. Establishing qualification and acceptance test network.

f. Documenting the development, qualification, and acceptance test networks.

13. Establish a Development Test Program Schedule consisting of:

a. Providing integrated ground test schedules for development, qualification, and acceptance.

b. Providing integrated flight test schedules for development, qualification, and acceptance.

c. Identifying booster and orbiter test schedule interfaces and constraints.

d. Integrating test program schedule requirements with those for facilities and support equipment.

WBS Number: 2.1.1
Integration Tasks (Cont)

14. Evaluate and document the results of the company sponsored effort relating to:

    a. Definition of test criteria and approach, checkout philosophy and concepts.

    b. Preparation and update of test inputs to the System Definition Handbook.

    c. Delineation of major test vehicles and subsystem elements.

WBS Number: 2.1.1
Orbiter Tasks

Company:	Function:	Manager:
NR	System Engineering	J. Bates

1. Evaluate and document the results of the company sponsored Radiation Survivability trade study for application to the contract effort. This trade study consists of defining additional program cost and associated vehicle weight related to provisions for radiation survivability. Three levels of radiation protection will be evaluated for other high cross range orbiter configurations.

2. Evaluate and document the results of the company sponsored shuttle vehicle and space station common equipment usage trade study. Impact of Space Station Docking and Stabilization Methods and Passengers and Cargo Transfer in Space trade study results will be considered in identification. The objective of this study is to identify subsystems and assemblies between the booster and orbiter which have a high probability of being common and would result in reducing development and operational costs of the shuttle program.

3. Prepare the orbiter system integrated schematic block diagram; coordinate the preparation of and review subsystem SBD's.

4. Analyze and expand functional analysis as required to define and document performance and subsystem design requirements for the orbiter vehicle. Coordinate this activity with WBS 2.4.5.

WBS Number: 2.1.1
Orbiter Tasks (Cont)

5. Prepare and maintain the sections of the SDH that relate exclusively to the orbiter vehicle.

6. Coordinate with orbiter subsystems design groups to prepare and maintain the orbiter portion of the Shuttle System Master Measurement and Control Requirements Document.

Company:	Function:	Manager:
NR	Integrated Electronics	G. C. Anderson

7. In support of Radiation Survivability trade study establish requirements associated with ground controlled recovery of an orbiter after exposure to a nuclear event.

8. Provide support for the technical analysis of mission and system requirements, in establishing the Space Shuttle Master Measurements and Control Requirements document and in preparation of documentation of requirements and other program integration tasks.

WBS Number: 3.1.1
Booster Tasks

Company:	Function:	Manager:
GD	System Integration	H. M. Bonesteel

1. Support NR planning of integrated trade studies by submittal of task descriptions and schedule estimates for the GD portions of the trades.

2. Support NR functional analysis to the second level of detail in order to define functional requirements for the space shuttle systems.

3. Perform planning and internal integration of those trade studies which are restricted to the booster or which have been identified as Convair responsibility. Planning will include identification of constraints on, and requirements for, the ground elements and other interfacing items.

WBS Number: 3.1.1
Booster Tasks (Cont)

4. Coordinate, integrate, and control the space shuttle to launch facility ICD (to be included in Volume I of the SDH). Prepare, coordinate, integrate, and control the booster portions of Volume II of the SDH.

5. Test requirements will be prepared based on definition of design/ performance requirements, mission objectives, and program plans. This consists of:

   a. Defining development test requirements, qualification and reliability test requirements, and acceptance test requirements.

   b. Integrating the development, qualification, and acceptance test requirements (including R&QA test requirements) into the test network.

6. Develop test program networks and document the development, qualification, and acceptance test networks.

7. Establish a development test program:

   a. Support integrated ground test schedules for development, qualification, and acceptance.

   b. Support integrated flight test schedules for development, qualification, and acceptance.

   c. Integrate test program schedule requirements with those for facilities and support equipment.

8. Evaluate and document the results of the company sponsored effort related to:

   a. Definition of test criteria and approach and of checkout philosophy and concepts.

   b. Preparation and update of test inputs to the system definition handbook (SDH).

   c. Delineation of major test vehicles and subsystem elements.

SPACE SHUTTLE PHASE B
TASK DESCRIPTIONS

WBS TITLE: MISSION ANALYSIS

WBS Number: 2.1.2
Integration Tasks

Company:	Function:	Manager:
NR	Flight Technology	N. F. Witte

The integration tasks for this WBS item are defined in WBS 1.1.

WBS Number: 2.1.2
Orbiter Tasks (Ref. WBS 1.2 for Integration Task)

Company	Function:	Manager:
NR	Flight Technology	N. F. Witte

1. On-Orbit Maneuver.

   a. Define on-orbit ΔV requirements and orbital parameters for the baseline and alternate missions including the effects of dispersions due to performance, orbit insertion, and launch time tolerances and the constraints of lighting and navigation requirements.

   b. Provide orbital flight profiles including timelines and ΔV burn attitudes in support of TCS and EC/LSS analyses and trade studies.

   c. Evaluate and document, for application to the contract effort, the results from the company sponsored Vehicle Alternate Missions Capability trade study which includes the following tasks:

      (1) Define the on-orbit mission profiles for as many alternate space shuttle missions as practical (from projected U.S. Space Program data).

WBS Number: 2.1.2
Orbiter Tasks (Cont)

(2) Define the baseline SSV alternate mission capability in terms of mission altitude, orbit inclination, and payload weight.

(3) Evaluate and document SSV design changes required to increase the alternate mission capability.

2. Orbiter Entry.

a. Define reference and design entry trajectories to determine design criteria for structures TPS and guidance-navigation-control design and analysis efforts.

b. Evaluate and document, for application to the contract effort, the results from company sponsored orbiter entry studies which include the following tasks:

(1) Formulate and incorporate modifications to the entry flight simulation digital computer programs which will improve the capabilities for defining minimum heating flight modes with required lateral ranging capabilities.

(2) Formulate and program entry guidance techniques for space shuttle type vehicles.

(3) Perform parametric studies pertaining to entry ranging capabilities as a function of entry conditions as influenced by deorbit position and impulse vector errors.

c. Evaluate and document a company sponsored task which supports the Powered vs. Unpowered Orbiter Landing trade study for application to the contract effort. This task will define the impact on the orbiter-entry-flight modes and guidance-and-navigation requirements due to removal of the orbiter A/B engines.

3. Flight Test.

a. Evaluate and document the following company sponsored studies for application to the contract effort.

(1) Determine orbiter alone flight profiles which will provide flight conditions for design and performance flight verification.

WBS Number 2.1.2
Orbiter Tasks (Cont)

(2) Define maximum flight test capabilities for horizontal and vertical launch modes considering structural limits, safety, crew tolerances, and test range limitations.

4. Crew Systems Support.

a. Evaluate and document the results of the company sponsored efforts as follows:

b. Identify crew performance capabilities and limitations based on mission analysis environmental requirements and the selected Phase B shuttle configuration.

c. Determine hazards associated with mission profiles and evaluate effects on the safety of the shuttle crew and passengers.

Company:	Function:	Manager:
NR	Systems Engineering	J. Bates

5. Define baseline and alternate mission requirements in terms of the mission orbital parameters; payload weight, size, shape, etc.; mission durations and projected traffic models.

6. Provide program cost analysis support to the "SSV Alternate Mission Capability" trade study.

WBS Number: 3.1.2
Booster Tasks

Company:	Function:	Manager:
GD	Flight Technology	S. V. Starr

1. Evaluate and document the following company sponsored tasks for applications to the contract effort:

a. Define and update a baseline booster return trajectory which has optimum flyback distance considering heating, loading, and flight control constraints.

WBS Number: 3.1.2
Booster Tasks (Cont)

b. Provide parametric booster return data as a function of staging conditions, aerodynamic characteristics, and air-breathing engine characteristics for use in trade studies.

c. Provide the trajectories and constraints for the booster-only test flights for both vertical and horizontal takeoffs.

d. Define the booster performance, structural and thermal loads, and flight control criteria required in support of the alternate mission trajectories within baseline design constraints.

Company:	Function:	Manager:
GD	Mission and Economic Analysis	M. Kantor

2. Assist in the definition of the baseline reference and alternate mission requirements for the booster through coordination with NR mission analysis study personnel and NASA.

3. Provide booster cost analysis data to support the Vehicle Propellant Distribution and Main Propulsion Sizing and the Alternate Mission trade studies.

SPACE SHUTTLE PHASE B
TASK DESCRIPTIONS

WBS TITLE: OPERATIONS ANALYSIS

WBS Number: 2.1.3
Integration Tasks

Company:	Function:	Manager:
NR	System Engineering	J. Bates

1. Prepare operations models resulting from ground and flight operations analyses. Provide technical direction to American Airlines for ground operations tasks. Assemble results of SD, GD, and American Airlines SRA and maintenance models programs (man-hours, skills, facilities support requirements, support equipment, transportation requirements, propellant supply, supply support) and optimized timelines as input data for models. Use resulting models and data to support major ground facilities trades, operations planning-and-cost analyses (Ref. 1.2).

2. Define flight-operations interface requirements between shuttle and space station, experimental modules, unmanned satellites, space tugs, communications satellites, and ground facilities.

3. Analyze and integrate orbiter and booster data so that ascent and landing modes are compatible. Integrate data into preparation of functional flow diagrams, timelines and operational procedures (Ref. 1.2).

4. In conjunction with Operation Site Evaluation Study, provide and evaluate the following data:

    a. Trajectory data from KSC, Edwards AFB, White Sands and other potential sites.

    b. Orbiter joint design inputs for GD.

    c. Orbiter cross range capability.

    d. Recommendations for specific operation sites.

WBS Number: 2.1.3
Orbiter Tasks

Company:	Function:	Manager:
NR	System Engineering	J. Bates

5. Establish flight and ground operational concept for the baseline mission. Develop the reference mission flight operations concept describing the sequence of events and operations from launch to landing for use in the operations plan document. Develop the orbiter ground operations concept from landing to launch. Support GD vehicle launch operations concept study in the areas of mating, transporting, erecting, pad integration, preflight checkout, propellant loading, and countdown-and-launch requirements. Document, maintain, and update the baseline operational concept to reflect current position. This will include providing detailed descriptions of the mission profile defining all ground operations and associated facilities for each vehicle from landing to launch, establishing over-all mission and ground operations timelines, and defining mission support systems and facilities. Booster and orbiter operational interfaces will be identified, and the over-all logistics concept described.

6. Develop flight operational concepts and mission profiles for alternate missions including: (a) satellite placement and retrieval, (b) satellite service and maintenance, (c) delivery of propulsive stages and payload, (d) delivery of propellants, and (e) short duration orbital mission. Describe sequence of events, operations and timelines for on-orbit phases of missions. Develop functional flow diagrams down to the second level. Support trade studies on alternate mission capability by providing data on possible missions including orbital parameters and payload characteristics. Prepare input data on alternate missions for operations plan. Document, maintain, and update alternate mission concepts to reflect current mission planning.

7. Identify requirements for orbiter ground and flight operations to include: Identification of major physical, functional, and procedural requirements between orbiter and the landing site, maintenance-and-launch facilities, boosters, space station, and satellites/experiment modules; identification of major physical, functional, and procedural requirements between orbiter and ground checkout, servicing, handling, maintenance systems, and flight systems.

8. Provide support to system safety analysis (Ref. 2.1.4) by conducting a safety analysis (limited to operational safety aspects) covering all

aspects of ground, launch, mission, and recovery operations. Consideration will be given to abort requirements. Gross hazards to personnel and hardware, covering the above phases, will be identified, described and classified.

9. Analyze data and recommend operational procedures for cargo and storables loading and unloading trade study.

10. Support operational site evaluation trade study of candidate sites for launch, recovery, and maintenance operations of the shuttle, including the two primary sites, ETR and WTR, and of other potential locations such as White Sands and Edwards AFB. Prepare a site evaluation summary to contain the following data:

    a. Range safety considerations for all azimuth launch trajectories, vehicle fly-back trajectories, vehicle abort trajectories, and availability of alternate airports for each candidate site. Define also the environments (weather, etc.) for each of those candidate sites.

    b. Operational hazards involved at each site considered, including environmental hazards to local populations (nuclear, air pollution, noise), weather hazards to operations, violation of foreign countries' air space, and possible accidents from launch and recovery aborts.

    c. Possible conflicts of the shuttle operations with other possible high priority uses of the candidate operational sites.

    d. New facilities which would be required at each candidate site and the modifications to existing facilities which are required to conduct efficient shuttle operations.

    e. Vehicle performance from each site considered in terms of optimum trajectories, payload delivered to orbit, and consumables used for the baseline and the alternate missions and abort trajectories.

11. Evaluate and document the following tasks as part of a company sponsored mission model study:

    a. Derive a mission and payload traffic model describing characteristics, frequencies, and launch dates of reference and alternate missions.

WBS Number : 2.1.3
Orbiter Tasks (Cont)

b. Define for each mission type, orbital parameters, on-orbit performance requirements, and mission peculiar launch-and-return constraints.

c. Define payload characteristics for each mission type including descriptions of payloads, dimensions, weights, specific environmental control, and handling-and-deployment constraints.

d. Identify selected areas of alternate mission and payload operations to define requirements for expanded shuttle capability. Among these payloads are propulsive, nuclear, and tug stages, singular and multiple satellites, and space rescue equipment.

12. Refine operations analysis performed in Phase B contractual tasks to support company sponsored efforts to define Phases C and D. In support of flight operations, perform detailed analysis of functions, interfaces, orientation, and trajectories for baseline and alternate missions using data derived during Phase B. Provide detailed timelines for crew, systems, and subsystems. In support of ground operations, perform analyses to provide details of all ground operations for Orbiter and NR/SD support operations to Booster. Provide detailed timelines for maintenance, repair, refurbishment, launch, etc., so that turnaround time can be defined in depth. Evaluate alternate system designs evolved during Phase B with respect to flight operations and ground operations for for Phase C and D.

13. As part of a company sponsored operations site study, perform and document the following tasks:

a. Collect data that has been developed during in-house and contractual studies relative to operational site evaluations for a reusable space shuttle system.

b. Evaluate requirements for operational site integration.

c. Analyze the above data to provide complete definition of the requirements for an operational site (new or modified). Prepare a section of the Shuttle Phase C and D proposal for the integrated operational site.

WBS Number: 2.1.3
Orbiter Tasks (Cont)

Company:	Function:	Manager:
NR	Flight Technology	N. F. Witte

14. Develop preliminary crew and passenger loading procedures. Develop crew, passenger, and ground operations personnel emergency egress procedures, and preliminary hardware requirements for the launch vehicle. Develop preliminary crew communications control and checkout requirements.

Company:	Function:	Manager:
NR	Integrated Electronics	G. C. Anderson

15. Define preferred ground based and satellite communications and tracking networks, coverage, data handling, and processing. Provide Shuttle Guidance and Navigation concepts and capabilities, project state-of-the-art for navigation and landing aids, and ground checkout criteria. From this derive vehicle and payload electrical power consumption profiles for baseline and alternate mission (nominal and contingency) during ground phases, and define major interfaces between IAS and ground systems, principally, data flow, ground commands, and facility requirements.

Company:	Function:	Manager:
NR	Operations and Test	W. Edson

16. Support operations analysis efforts to define test and checkout operations conducted during turnaround (postflight, maintenance, prelaunch and launch operations).

17. Develop logistics and support concepts for ground operations and maintenance of the orbiter subsystems and equipment by defining the Space Shuttle maintenance concept and the levels of support in terms of basic capabilities. Assist in definition of concept and methods for transporting the orbiter, major subassemblies and major support equipment to launch site. Define concepts and methods, through the maintenance cycle, for the transporting of equipment, fluids, propellants and coolants to

WBS Number: 2.1.3
Orbiter Tasks (Cont)

ferry and alternate recovery sites. Handling and storage of environmentally sensitive spare parts and materials shall be defined, together with facilities requirements peculiar to vehicle and equipment maintenance.

18. Support trade studies by defining the impact of design options on total support requirements.

19. Prepare Support Requirements Analysis (SRA) data inputs and analyze results to determine progress toward attainment of support objectives.

20. Prepare inputs to Volume III, Part IV, of the Systems Definition Handbook (SDH).

Company:	Function:	Manager:
American Airlines	Operations Analysis	J. Amacker

21. Crew/passenger loading: assist in determination of efficient loading systems.

22. Cargo loading: assist in providing maintainability concepts for various cargo loading schemes. Requirements for special handling and packaging of cargo will also be considered.

23. Maintenance turnaround analysis: provide by program models the scheduled maintenance and service task allocation and scheduling consistent with performance of phased maintenance inspections. Provide data from computer assisted maintenance management for the performance of both scheduled and unscheduled tasks. Data will include maintenance task sequence, man-hours (skill and type), facilities support requirements, support equipment, technical data, supply support, propellant supply, and transportation.

Company:	Function:	Manager:
NR	Preliminary Design	W.A. Martin

24. Define recommended ground support equipment (GSE) needed for the orbiter flight vehicles of the space shuttle system. The design data will support functional analyses of post-flight maintenance, pre-launch, and launch operations to be prepared by Systems Engineering.

WBS Number: 3.1.3
Booster Tasks

Company:	Function:	Manager:
GD	Operations	P.M. Prophett

1. Establish booster flight and ground operational concept for the baseline mission. Define the reference mission concept describing the sequence of events and operations from launch to landing for use in the operations plan. Define the booster ground operations concept from landing to launch and integrate orbiter support inputs to comprise a total ground operations concept including mating, transporting, erecting, pad integration, propellant loading, and countdown-and-launch activities.

2. Define booster operational ground support equipment (GSE) and facilities necessary to implement the operations identified in Task 1. Integrate orbiter GSE and facilities input requirements from WBS 2.1.3 and define complete space shuttle system, ground operations, GSE, and facilities.

3. Identify requirements for booster ground and flight operations to include: identification of major physical, functional, and procedural interface requirements between the booster and the landing site, maintenance and launch facilities, and orbiters; and identification of major physical, functional, and procedural interface requirements between the booster and ground checkout, servicing, handling, and maintenance and flight systems.

4. Conduct operations-site evaluation trade study to include:

    a. Simulate nominal and polar trajectories for the space shuttle vehicle from KSC, WTR, Edwards AF Base, and White Sands. Compare payloads and other operating characteristics. Adapt system-level mission requirements and required cost and effectiveness evaluation data to evaluate the various operational sites. Evaluation will consider (1) location of manufacturing facility and engine test facility, (2) hazards, (3) weather and environmental pollution, (4) performance, and (5) costs. Coordinate and direct specific point design cost estimation studies.

    b. Using cost inputs from NR, estimate total program costs for each of four operational sites. Adapt point designs of operational site GSE and facilities to four operational sites.

    c. Coordinate with NR for point design inputs.

WBS Number: 3.1.3
Booster Tasks (Cont)

d. The results of this study will be documented and will quantify the above considerations in terms of operational effectiveness, mission accomplishment and effectiveness, use of existing facilities, compatibility with vehicle system design and operational concepts, and costs.

5. Define baseline booster logistics and support concepts to include maintenance functions required, maintenance location, repair and/or replace criteria, spares requirements; vehicle, subsystem and support equipment transportation requirements; and consumable materials requirements. Coordinate company sponsored studies which quantify operations and logistics support resource requirements through systems engineering and support requirements analysis procedures in the areas of:

   a. Personnel—by type and skill level

   b. Training and training equipment

   c. Ground support equipment

   d. Facilities

   e. Support technical data

   f. Spares

6. Coordinate all booster operations analysis and system ground operations analysis efforts; and provide required support to NR in the areas of preliminary servicing concepts and preliminary operations site capability data. Provide similar data to support preparation of booster and ground operations sections of the Space Shuttle Operations Plan.

Company:	Function	Manager:
GD	Preliminary Design	R.A. Lynch

7. Provide booster configuration definition support to operations site evaluation trade study to include site location performance impact on straight versus delta wing booster and flyback engine type and installation.

WBS Number: 3.1.3
Booster Tasks (Cont)

Company:	Function:	Manager:
GD	Flight Technology	S.V. Starr

8. Define booster flight characteristics for alternate booster configurations and provide related flight performance synthesis support for the operational site evaluation trade study.

Company:	Function:	Manager:
GD	Mission and Economic Analysis	M. Kantor

9. Provide mission and economic analysis support to all operations analysis trade studies and design analysis tasks identified under basic tasks above. Define mission and cost analysis evaluation criteria to be applied; and develop and implement required evaluation techniques in support of these trade studies and design analyses.

Company:	Function:	Manager:
GD	Subsystems Engineering	L.E. Lightbrown

10. Coordinate and provide vehicle subsystems support to operations analysis studies to define integrated electronics, structures and TPS, propulsion, and power and fluid subsystems test and checkout operations requirements conducted during turnaround (post flight, maintenance, prelaunch and launch) operations. Provide similar support to operations site evaluation and transport, erection, mating, and servicing trade studies.

Company:	Function:	Manager:
GD	Logistics	A.H. Gross

11. Support operations analysis by developing and defining concepts for maintenance of booster subsystems and equipment. Define space shuttle maintenance concept and levels of support in terms of basic capabilities. Assist in definition of concepts and methods for transporting the booster, major subassemblies and support equipment to the launch site. Define handling and storage requirements of environmentally sensitive spare parts and material, together with facility requirements peculiar to vehicle and equipment maintenance.

12. Support trade studies by defining impact of design options on total support requirements.

WBS Number: 3.1.3
Booster Tasks (Cont)

13. Prepare support requirements analysis (SRA) data inputs and analyze results to determine progress toward attainment of maintainability design objectives and logistic support goals.

Company:	Function	Manager:
GD	GSE and Facilities	M.E. Stone

14. Provide operational GSE and facilities design analysis and trade study support based on identified requirements in the following areas. Utilize inputs from company sponsored studies.

    a. Conduct a vehicle mating, transporting and erecting servicing concepts trade study to determine the optimum sequence for booster and orbiter mating, transporting, and erecting. Modification of existing Complex 39 facilities will be included. Prepare data for trade study report.

    b. Conduct design studies to define ground support systems to service the booster and orbiter during the ground turnaround cycle. Emphasis will be directed toward achieving commonality of systems.

    c. Conduct design studies to define new operational GSE and facilities to support the operational site evaluation trade study.

15. Provide company sponsored GSE and facilities design analysis and trade study support based on identified requirements in the following areas:

    a. Conduct a cryogenic propellant loading trade study which will investigate the techniques, design, and hardware considerations required to support the cryogenic propellant loading capability. Investigate sequential versus simultaneous loading, size, and number of loading lines. Prepare data for the trade study report.

    b. Conduct supporting GSE and facilities studies and analysis utilizing the services of an A&E subcontractor:

        (1) Modification of existing KSC GSE and facilities.

        (2) Define new GSE and facility (for use other than KSC).

        (3) Define GSE for booster and orbiter subsystems (emphasize commonality).

        (4) Define new runway and safing facility.

WBS Number: 3.1.3
Booster Tasks (Cont)

Company:	Function:	Manager:
GD	Safety	H. Nulton

16. Provide system safety analysis support to operations concepts studies to include identification of potential hazards and remedial safety measures.

Company:	Function	Manager:
American Airlines	Operations Analysis	J. Amacker

17. Provide data and analytical support in the following areas:

    a. Vehicle launch operations concept: Provide airline ground support data to be used in definition of total vehicle ground operations.

    b. Ground turnaround operations: Provide consulting on tasks to be accomplished and their sequence.

    c. Mission operations: Provide airline mission experience to air-breathing portions of mission.

    d. Baseline logistic and support concepts: Assist with airline sparing concepts.

    e. Vehicle transportation requirements: Provide airline assistance on ferry and alternative site support requirements.

SPACE SHUTTLE PHASE B
TASK DESCRIPTIONS

WBS TITLE: SYSTEM SAFETY ANALYSIS

WBS Number: 2.1.4
Integration Tasks

Company:	Function:	Manager:
NR	Safety	L.B. Gray

Note:

System safety hazard analysis tasks have been integrated into the WBS (work breakdown structure) packages for the participating functions. System safety will support the hazards analysis effort by preparing guidelines, providing procedures for conducting the analysis, and providing direct system safety support.

Specific System Safety Engineering Tasks include:

1. Provide, and periodically update, general system safety guidelines and criteria for the System Definition Handbook. These guidelines receive ERB approval and constitute design/operations requirements.

2. Review booster and orbiter integrated designs and trade studies and support the WBS analysts to assure proper identification, classification, and resolution of hazards.

3. Exchange hazard analysis sheets between SD and Convair to reduce duplication of effort and assure maximum system safety in the Space Shuttle Program.

4. Prepare integrated safety analysis input to final program report.

WBS Number: 2.1.4
Orbiter Tasks

Company:	Function:	Manager:
NR	System Analysis	L. B. Gray

Specific System Safety Engineering tasks include:

1. Provide system safety guidelines for specific orbiter systems and operations.
2. Provide procedures for hazard analysis preparation and processing and for coordination between system safety and other functions.
3. Provide Safety interface with Convair booster safety representatives.
4. Provide support and consultation to engineering functions during the preparation of hazard analysis in identifying, classifying, and reducing or eliminating hazards relating to orbiter systems and operations.
5. Review functional flow block diagrams and schematics to identify and classify hazards related to each function.
6. Maintain a listing of all identified hazards as either (a) open or (b) closed - include remedial measures and rationale for acceptance.
7. Provide safety inputs to the Space Shuttle System Specification and system CEI specifications, Part I, relating to the booster and orbiter systems and operations.

WBS Number: 3.1.4
Booster Tasks

Company:	Function:	Manager:
GD	Safety	H. Nulton

Specific System Safety Engineering tasks include:

1. Provide system safety guidelines for specific booster systems and operations.

WBS Number: 3.1.4
Booster Tasks (Cont)

2. Provide procedures for hazard analysis preparation and processing and for coordination between system safety and other functions.
3. Provide Safety interface with SD booster safety representatives.
4. Provide support and consultation to engineering functions during the preparation of hazard analysis in identifying, classifying, and reducing or eliminating hazards relating to orbiter systems and operations.
5. Review functional flow block diagrams and schematics to identify and classify hazards related to each function.
6. Provide, and periodically update, general system safety guidelines and criteria for the System Definition Handbook. These guidelines receive ERB approval and constitute design and operation requirements.
7. Maintain a listing of all identified hazards as either (a) open or (b) closed - include remedial measures and rationale for acceptance.
8. Provide safety inputs to the system CEI specifications, Part I, relating to booster systems and operations.
9. Prepare integrated safety analysis input to final program report.

SPACE SHUTTLE PHASE B
TASK DESCRIPTIONS

WBS TITLE: SYSTEM FLIGHT CHARACTERISTICS

WBS Number: 2.1.5
Integration Tasks

Company:	Function:	Manager:
NR	Flight Technology	N. F. Witte

1. Aerodynamic Configuration Design: Conduct aerodynamic configuration studies to support system definition and final preliminary design of the combined booster and orbiter configurations (Ref. 1.2).

   a. Support the propellant distribution and main propulsion sizing trade. Develop parametric data on lift, drag, and center of pressure for a range of vehicle sizes, and base geometries.

   b. Develop aerodynamic force and moment data on the integrated system.

   c. Evaluate and document the following company sponsored tasks for applications to the contract effort:

      (1) Define preliminary aerodynamic characteristics of the combined configurations during launch using estimated interference factors.

      (2) Develop parametric data on lift, drag, and center of pressure as affected by geometry, and orbiter/booster location and alignment to support the orbiter position on booster trade.

2. Flight Performance Characteristics: Launch performance is conducted under WBS 2.1.2 and referenced in WBS 1.2.

3. Stability and Control Analysis: Perform studies to determine the static stability characteristics of the combined orbiter and booster configurations (Ref. 1.2).

WBS Number: 2.1.5
Integration Tasks (Cont)

a. Develop design criteria for aerodynamic stability during launch for aerodynamic control, and specify center of gravity boundaries.

b. Support preparation of the System Definition Handbook by providing launch stability requirements and characteristics for the baseline and final preliminary design configurations.

c. Evaluate and document the following company sponsored tasks for applications to the contract efforts.

(1) Conduct studies to define preliminary static stability characteristics of the two orbiter baseline configurations in the presence of the booster.

(2) Define preliminary longitudinal and lateral-directional stability characteristics of the combined system using GD-provided booster data.

(3) Define wind tunnel test requirements to determine the combined system stability characteristics as affected by orbiter and booster position, geometry, and flight condition.

(4) Conduct analyses of wind tunnel results and develop stability derivatives for launch control analysis of the final preliminary design configurations.

4. Airloads Analysis: Definition of aerodynamic data to define design airloads and venting requirements is conducted under WBS 2.2.2.

5. Wind Tunnel Program: Plan and conduct a wind tunnel program, as approved by NASA, to provide ascent heating, force, moment, and pressure distributions for the combined orbiter and booster configurations.

a. Provide test data obtained in government facilities to NASA compatible with the SADSAC data management system as specified in Appendix A of the SOW.

b. Evaluate and document the following company sponsored tasks for applications to the contract efforts:

WBS Number: 2.1.5
Integration Tasks (Cont)

(1) Coordinate with GD and define test requirements including facilities, schedule, model scale and configuration, data reduction, and instrumentation. NR and GD facilities will be used together with the government facilities specified in Appendix B of the SOW.

(2) Plan and schedule wind tunnel program, coordinating NR and GD requirements with NASA and the test facilities.

(3) Modify orbiter models for combined system tests.

(4) Conduct combined system force, moment, and pressure tests. Provide engineering and model technician support at the test site. Support GD in launch heating tests.

(5) Analyze, correlate, and document force, moment and pressure distribution data to support definition of stability characteristics of the combined configuration, and distributed and component airloads on the orbiters in presence of the booster. Investigate possible differences between wind tunnel and flight aerodynamic characteristics.

(6) Analyze, correlate and document orbiter launch heating data to determine best prediction method for vehicle design.

WBS Number: 2.1.5
Orbiter Tasks

Company:	Function:	Manager:
NR	Flight Technology	N.F. Witte

1. Aerodynamic Configuration Design: Conduct aerodynamic analyses to support system definition, design trades, and to provide aerodynamic data for final preliminary design. The following contract tasks will be performed:

   a. Provide basic aerodynamic force and moment coefficients for a design data book which will be used for subsystem design.

   b. Define configuration design requirements, including aerodynamic surface geometry, atmospheric flight attitudes, pressure loadings, and flight limits.

WBS Number: 2.1.5
Orbiter Tasks (Cont)

c. Provide orbiter aerodynamic characteristics to support the following major trade studies:

   (1) Vehicle alternate mission capability.

   (2) Vehicle abort study.

   (3) Straight versus delta wing orbiter for 200 nautical miles cross range.

d. Provide GD with orbiter aerodynamic characteristics in the presence of booster to support the booster and orbiter separation concept trade.

e. Evaluate and document results of the following company sponsored studies for application to the contract effort.

   (1) Conduct studies to define the effects of the following configuration variables on aerodynamic performance, trimmability, stability, and control.

   - Wing geometry, sweep, aspect ratio, size, and airfoil
   - Tail type, geometry, size, and location
   - Control surface type, size, location, and hinge line orientation
   - Flaps versus no flaps
   - Fuselage platform, area distribution, camber, nose body contour, body slope, corner radius, and base area

2. Flight Performance Characteristics: Define the atmospheric performance characteristics of the orbiter (entry characteristics are defined under Ref. 2.1.2).

   a. Define flight performance criteria relating to operational safety including mission profiles and landing footprint.

   b. Define takeoff, cruise, approach, and landing characteristics to support the following major trade studies:

      (1) Self ferry capability (orbiter).

WBS Number: 2.1.5
Orbiter Tasks (Cont)

(2) Powered versus unpowered orbiter landing.

(3) Hydrogen versus JP airbreathing engines (orbiter).

(4) Unmanned versus manned flight test.

(5) Hypersonic testing approach.

c. Define takeoff, cruise, maneuvering approach, and landing characteristics for related orbiter designs.

d. Evaluate and document results of company sponsored studies for application to the contract. This effort includes the definition of parametric performance data related to orbiter size, weight, and configuration geometry.

3. Stability and Control Analysis: Perform the following contract effort:

a. Develp design criteria for aerodynamic stability during entry, transition, cruise, takeoff, and landing. Specify center-of-gravity limits for satisfactory control.

b. Define static and dynamic stability characteristics of the selected orbiter concepts. Establish stick-fixed stability and response to control surface deflection. Identify handling qualities during orbiter alone flight.

c. Conduct a vehicle transition control trade study for the straight wing orbiter. Compare gradual transition from high to low angle of attack at supersonic speed to rapid transition at subsonic speed.

d. Support the following major trade studies by providing data on stability and control characteristics and control surface effectiveness:

(1) Flight control system optimization

(2) Vehicle abort capability

(3) ACPS configuration

WBS Number: 2.1.5
Orbiter Tasks (Cont)

e. Support preparation of the System Definition Handbook by providing orbiter stability requirements and characteristics for the baseline and final preliminary design configurations.

f. Evaluate and document results of the following company sponsored studies for application to the contract:

(1) Define static stability characteristics of the two baseline orbiters.

(2) Define preliminary longitudinal and lateral-directional dynamic stability and control characteristics of the baseline orbiters.

(3) Define handling qualities in terms of MIL-F-8785B specification and/or other suitable criteria at selected points along the nominal entry trajectory, transition, cruise, takeoff modes, and landing modes.

4. Wind Tunnel Program

a. Plan a wind tunnel program, as approved by NASA, to provide force, moment, heating, and pressure distributions for the orbiter alone configurations using NR and government facilities specified in Appendix B of the SOW.

b. Provide test data obtained in government facilities to NASA compatible with the SADSAC data management system as specified in Appendix A of the SOW.

c. Evaluate results of the following company sponsored effort for application to the contract:

(1) Define test requirements including facilities, schedule, model scale and configuration, and data reduction, and instrumentation. Coordinate test requirements with NASA and the test facilities.

(2) Design and fabricate orbiter models.

(3) Conduct combined system force, moment, and pressure and heating tests. Provide engineering and model technician support at the test site.

WBS Number: 2.1.5
Orbiter Tasks (Cont)

(4) Analyze, correlate, and document force, moment and pressure distribution data to support definition of stability characteristics and distributed and component airloads for the orbiter configurations. Investigate possible differences between wind tunnel and flight aerodynamic characteristics.

(5) Analyze, correlate, and document orbiter entry heating data to determine best prediction method for vehicle design.

Company:	Function:	Manager:
NR (Honeywell, Inc.)	Integrated Electronics	G. Anderson (L. Hudson: HI)

5. This task will be accomplished by the GN&C Subcontractor, Honeywell, Inc. (HI) under the technical direction, monitoring and approval of NR integrated electronics, under contract funds. The HI efforts are detailed under WBS 2.3.2. HI will conduct the flight control system optimization trade study, specify control modes for each mission phase and synthesize the appropriate control system configuration, perform subsystem design studies using analog and digital simulations, identify attitude control system ΔV requirements for perturbations caused by wind shears, engine failure, and center-of-gravity shift.

WBS Number: 3.1.5
Booster Tasks

Company:	Function:	Manager:
GD	Flight Technology	S.V. Starr

1. Aerodynamic Configuration Design: Conduct aerodynamic configuration studies to support system definition and final preliminary design of the booster configuration.

   a. Provide aerodynamic characteristics data and narrative for the System Definition Handbook for the baseline and final preliminary design configurations.

   b. Evaluate and document the following company sponsored studies for application to the contract effort:

      (1) Define preliminary aerodynamic characteristics of the booster, including estimate of interference effects, and supply to NR.

WBS Number: 3.1.5
Booster Tasks (Cont)

(2) Provide aerodynamic characteristics to support the straight-stowed delta-wing trade study.

2. Flight Performance Characteristics: Perform studies to determine the booster flight performance characteristics.

   a. Submit results of task 3 to the Systems Definition Handbook.

   b. Booster flyback, approach, and landing performance is conducted under WBS 3.1.2.

   c. Evaluate and document the following company sponsored studies for application to the contract effort:

      (1) Define the booster performance characteristics for ferry operations, including takeoff, climb, cruise, and landing.

3. Stability and Control Analysis: Perform studies to determine static and dynamic stability characteristics of the booster.

   a. Provide stability requirements and characteristics writeup for the System Definition Handbook for the baseline and final predesign configurations.

   b. Evaluate and document the following company sponsored studies for application to the contract effort:

      (1) Define the preliminary static stability characteristics of the straight-stowed delta-wing configurations.

      (2) Develop design criteria for aerodynamic stability for the booster flight from staging through landing and ferry operations. Specify permissible range of center-of-gravity locations.

      (3) Conduct analyses of wind tunnel test results and develop stability derivatives for booster control analysis of the final preliminary design configuration.

      (4) Provide aerodynamic and control data required to determine the most efficient utilization of aerodynamic surfaces, thrust vector control, attitude control propulsion for the booster flight phases to support the flight-control system optimization trade study.

WBS Number: 3.1.5
Booster Tasks (Cont)

(5) Provide booster heating, structural loads, and control system data associated with both rapid and gradual transition from supersonic to subsonic speeds in support of the vehicle-transition control trade study.

4. Wind Tunnel Program: Plan and conduct a wind tunnel test program, as approved by NASA, to provide heating, force, moment, and pressure distributions on the booster.

a. Provide test data obtained in government facilities on the above tests to NASA compatible with SADSAC data management system as specified in Appendix A of SOW.

b. Evaluate and document the following company sponsored studies for application to the contract effort:

(1) Coordinate with NR and define test requirements including facilities, schedule, model scale and configuration, data reduction, and instrumentation. GD facilities will be used together with the government facilities specified in Appendix B of the SOW.

(2) Assist NR with planning and scheduling activities.

(3) Design and fabricate booster models.

(4) Conduct the following portions of the over-all test program:

- Force, moment, heating, and pressure distribution on the booster configurations during entry phase.
- Force and moment on the booster and orbiter during staging and separation.
- Heating on the booster and orbiter during launch phase.

(5) Analyze, correlate, and document force, moment and pressure distribution data to support definition of stability characteristics of the booster only configuration; and distributed and component airloads on the booster.

WBS Number: 3.1.5
Booster Tasks (Cont)

Company:	Function:	Manager:
GD	Flight Technology	S.V. Starr

in the presence of the orbiter.

(6) Analyze, correlate, and document booster launch and entry heating data to determine best prediction method for vehicle design.

SPACE SHUTTLE PHASE B
TASK DESCRIPTIONS

WBS TITLE: MANUFACTURABILITY

WBS Number: 2.1.6
Integration Tasks

Company:	Function:	Manager:
NR	Manufacturing	J. W. Cuzzupoli

1. Coordinate and implement data exchange between NR and GD/C in order to realize maximum cost savings relative to manufacturability of hardware, Manufacturing engineering's participation with trade and design studies, technological state-of-the-art concepts, commonality of hardware and software systems, and related company-sponsored research and development processes.

WBS Number: 2.1.6
Orbiter Tasks

Company:	Function:	Manager:
NR	Manufacturing	J. W. Cuzzupoli

1. Develop manufacturing criteria for evaluation of alternative design concepts. These criteria shall include consideration of producibility parameters required to determine basic feasibility of design concept for structural and system elements. The feasibility criteria shall be further defined to provide for evaluation of relative merits of candidate designs in terms of total fabrication costs considering production requirements, detail, detail sub-assembly, and top level testing requirements, tool requirements, installation requirements, and schedule and rate considerations. Additionally, the manufacturability of all hardware will be a major factor in the design selection during manufacturing trade and design studies.

2. Apply manufacturability criteria to design trades and concept evaluation, Establish and maintain an interface with design and laboratory functions to assure utilization and application of manufacturability and testability

WBS Number: 2.1.6
Orbiter Tasks (Cont)

criteria in development of design data and selection of optimum concept. Participate in engineering review board considerations of trade selection and baseline changes. Assist in make-or-buy decisions.

3. Document manufacturability considerations and recommendations applied to trade study selections and baseline changes. This documentation will be formalized through utilization of a manufacturability design evaluation criteria form submitted to the engineering review board.

4. Evaluate and document the results of the following company sponsored* efforts which are to provide early definition and parametric requirements to Phase B baseline trade studies for manufacturability. Data and analysis will be presented to e.g., (Engineering, Business Operations, etc.,) management for evaluation, explanation, and recommendation of efforts.

5. Manufacturing technology studies

Trade Study or Task	Study Alternatives and Variables	Approach and Considerations
TPS Panels*	Processing of: Coated Columbium Haynes 188 TD NiCr coating methods	Evaluate machining and forming. Develop joining techniques by diffusion bonding and brazing. Evaluate and develop repair techniques. Study new coating methods.
Insulation*	Processing of: Foam (LH_2 Tanks) Aluminized Mylar (HPI) Batt type (Dynaflex, Min K, etc.)	Evaluate materials for spray foaming and develop fabrication techniques including machining and sealing. Develop

WBS Number: 2.1.6
Orbiter Tasks (Cont)

Trade Study or Task	Study Alternatives and Variables	Approach and Considerations
Insulation*		fabrication methods and tooling concepts. Evaluate joining, attachment, humidity protective coating, packaging and handling concepts.
Welding*	Processing of: Large thin wall aluminum tank. Small diameter tubing	Evaluate pulse TIG machine welding process. Evaluate orbit pulsed welding of stainless steel and 6 AL-4V Titanium. Evaluate non-vacuum electron beam welding.
Flat Conductor Cable*	Processing of: End terminations vehicle applications	Develop terminal processing. Develop equipment and tooling requirements.
Ceramics, Reinforced Carbon Composites*	Processing of: Nose cones, leading edges	Investigate and develop manufacturing techniques for fabrication, joining and attachment of ceramics and pyrolyzed plastics.
*Company Sponsored		

WBS Number: 2.1.6
Orbiter Tasks (Cont)

Company:	Function:	Manager:
NR	Project Engineering	G.F. Fraser

6. Coordinate definition of manufacturability criteria between engineering and manufacturing departments. Coordinate manufacturing trade studies involving both engineering and manufacturing.

7. Establish drawing tree system for manufacturing.

WBS Number: 3.1.6
Booster Tasks

Company:	Function:	Manager:
GD/C	Manufacturing	D.L. Fagan (Prime)

1. Establish preliminary manufacturability criteria as a requirement for booster system design. Disseminate these criteria to the individual system design groups together with detailed consultations and expositions. Complete illustration and indoctrination of the design personnel, in the benefits of these criteria, are the goals of this effort.

2. Perform a series of manufacturing trade studies. The purpose of these studies will be to access the impact of manufacturing on various booster and space shuttle common system design consideration.

3. Provide the design engineers with detailed assistance to insure that their efforts result in products which are economically producible. Provide up-to-date manufacturing data.

4. Participate in engineering review board meetings presenting manufacturing inputs for decisions. Assist in make-or-buy decisions.

Company:	Function:	Manager:
GD/C	System Engineering	L.E. Munson (Support)

5. Provide direction and guidance with regard to the conduct of the trade studies. Integrate the manufacturing inputs with those from other elements of the study.

SPACE SHUTTLE PHASE B
TASK DESCRIPTIONS

WBS TITLE: ABORTS

WBS Number 2. 1. 7
Integration Tasks

Company:	Function:	Manager:
NR	System Engineeeing	J. Bates

1. Establish most probable and critical abort situations and associated conditions (based on company funded activities) and define the required abort requirements and capability analysis.

2. Evaluate baseline designs to define inherent safe mission termination capability and establish design and operational changes required for increased capability.

3. Define and document operational and flight test abort capabilities, limitations, techniques, and support requirements in support of Phase C and D efforts.

WBS Number 2. 1. 7
Orbiter Tasks

Company:	Function:	Manager:
NR	System Engineering	J. Bates

1. Evaluate and document the results of the following company sponsored abort studies for application to the contract effort.

   a. Definition or orbiter system and subsystem functional requirements to support preliminary subsystem definition and operational description.

   b. Preparation of an abort matrix to organize and display abort study data.

WBS Number 2.1.7
Orbiter Tasks

c. Definition of abort situation time criticality.

d. Establishment of emergency shutdown and personnel debarkation requirements for pre-launch failure situations.

2. Evaluate orbiter ferry operations to define emergency capability requirements.

3. Define and perform detailed trade studies required to assess penalties associated with increased abort capability.

Company:	Function:	Manager
NR	Flight Technology	N. F. Witte

4. Evaluate and document the results of the following company sponsored abort studies for application to the contract effort.

   a. Establish orbiter pad separation requirements considering engine start time, thrust-weight ratio, separation and control system and the implication of time critical response requirements.

   b. Evaluate the effect of the number of orbiter engines on abort capability considering performance and reliability. Include abort to orbit as well as downrange abort landing sites.

   c. Establish minimum time from lift-off to safe orbiter separation, minimum time from lift-off at which abort to orbit can be accomplished and maximum time from lift-off at which orbiter return to launch site is possible. Evaluate requirements, procedures, etc., for return to launch site, abort to orbit, once-around abort situations, and downrange abort.

   d. Establish orbiter suborbital entry characteristics resulting from loss of thrust (thrust less than required for continuing to orbit), determine effects of propellant on board at entry and define fuel dump rates required to assure safe entry.

5. Investigate alternate methods to improve system abort capability and assess impact on design and performance in support of vehicle abort capability trade. Investigate crew operational capability to perform intact abort.

WBS Number 2. 1. 7
Orbiter Tasks (Cont)

6. Identify crew limiting conditions for intact abort and recovery operations.

7. Evaluate effect of orbiter engine(s) out (air breather) on operational and ferry mission performance and control requirements.

Company:	Function:	Manager:
NR	Reliability Engineering	L. B. Gray

8. Provide vehicle abort capability trade-off study support by providing critical function listings, failure mode identification, and relative reliability assessments to system engineering. Review the abort study outputs for completeness.

Company:	Function:	Manager:
NR	Vehicle Structures	R. A. Lusk

9. Provide structural analytical support to the vehicle abort trade-off study and the definition of affected system and subsystem functional requirements by identifying structural penalties associated with abort requirements. The effort will include evaluation of the nominal mission design to determine capability relative to abort imposed requirements and definition of the effects of imposing on the design abort aerodynamic and thermal loading requirements.

Company:	Function:	Manager:
NR	Integrated Electronics	G. C. Anderson

10. Evaluate nominal mission design to determine capability relative to abort imposed requirements.

11. Support the definition of subsystem design and operational modifications and penalties associated with abort requirements (trade studies).

WBS Number 2.1.7
Orbiter Tasks (Cont)

Company:	Function:	Manager:
NR	Fluid and Propulsion	R.E. Field

12. Define the propulsion system characteristics and operating constraints associated with the various abort modes and design alternatives. Define abort-oriented propulsion system design options. Determine performance and operating characteristics. Evaluate the impact of abort requirements on normal mission requirements.

WBS Number 3.1.7
Booster Tasks

Company:	Function:	Manager:
GD	Flight Technology	S. V. Starr

1. Evaluate and document the results of the following company sponsored studies for application to the contract effort.

   a. Establish allowable booster thrust loss as a function of time from liftoff. Define trajectory characteristics after thrust loss for flight with and without the orbiter. Define flight trajectory and procedures required to return booster after abort.

   b. Define baseline separation capability for premature separation considering flight control, orbiter engine start, booster engine shut down, dynamic pressure, and failure induced perturbations.

2. Investigate alternate booster flight trajectory procedures and separation system characteristics to improve abort capability; and assess the impact on design and performance in support of vehicle abort capability trade.

3. Evaluate airbreathing propulsion system failures with respect to performance and control requirements for design mission.

WBS Number 3.1.7
Booster Tasks (Cont)

Company:	Functions:	Manager:
GD	Operations	P. Prophett

4. Evaluate and document the results of the following company sponsored studies for application to the contract effort.

   a. Prepare an abort matrix for the booster relating failure situations to subsystems and mission phase indicating recommended procedures. Define time criticality of abort situations for booster support reliability in identifying critical subsystems. Assist in identifying potential changes which would improve abort capability and support abort capability trades.

   b. Define crew and ground personnel operational sequence procedures for abort situations.

5. Evaluate booster ferry operations to define emergency requirements.

Company:	Function:	Manager:
GD	Reliability	F. Lee

6. Perform FMEA for booster. Perform a reliability assessment of the booster subsystems with regards to identified failure modes and establish the relative probability of occurrence. Identify critical subsystem components.

Company:	Function:	Manager:
GD	Safety	H. Nulton

7. Evaluate and document the results of the following company sponsored studies for application to the contract effort.

   a. Establish emergency shut down and personnel debarkation requirements for prelaunch failure situations particularly for time crtical situations.

   b. Review booster abort study outputs for adequacy with respect to safety.

WBS Number 3.1.7
Booster Tasks (Cont)

Company:	Function:	Manager:
GD	Power and Fluids Systems	D. Krause

8. Establish booster crew pad abort escape system concepts and related design and operation requirements for time critical abort situations.

Company:	Function:	Manager:
GD	Propulsion	A. Schuler

9. Define the booster propulsion system characteristics and operating constraints associated with the various abort modes. Define abort oriented propulsion system modification.

Company:	Function:	Manager:
GD	Structures and TPS	F. Krohn

10. Provide structural analytical support to the vehicle abort trade study in terms of identifying structural penalties associated with improved abort capability.

Company:	Function:	Manager:
GD	Integrated Avionics	C. Grunsky

11. Define booster subsystem characteristics required by intact abort capability requirements. Define avionics ground equipment requirements necessary to support in-flight abort procedures. Support abort trade study in terms of identifying subsystem modifications required to improve abort capability.

SPACE SHUTTLE PHASE B
TASK DESCRIPTIONS

WBS TITLE: RELIABILITY AND QUALITY

WBS Number: 2.1.8
Integration Tasks

Company:	Function:	Manager:
NR	Reliability	L. B. Gray

1. Perform the necessary definition and direction to, and coordination with, Convair and subcontractors to ensure a compatible, uniform approach to the achievement of the reliability engineering objectives. The following tasks will be performed:

   a. Establish and maintain reliability criteria: Define reliability criteria during the early stages of the Phase B effort to allow utilization of these data in the alternate designs being considered. The following areas which may be influenced by Reliability will be considered: Redundancy, testability, inspectability, performance, maintainability, limited life and reusability.

   b. Generate Program Guidelines: NR shall develop a uniform approach to the implementation of all defined Reliability tasks performed during the Shuttle Phase B study. Early in the study, procedures, desk instructions, and data formats will be developed and imposed on associate and subcontractors to provide consistency in depth of activity and in data presentation. The following activities will be defined in detail:

      (1) Procedures and formats for Failure Mode Effect Analysis (including Single Failure Point Summaries and Critical Function Listings).

      (2) Trade study assessment techniques and trade check lists.

      (3) Management visibility and control procedures.

WBS Number: 2.1.8
Integration Tasks (Cont)

2. Support Customer Reviews: During the Phase B effort the contractor will conduct informal and formal reviews with the NASA. The informal reviews will provide communication between NASA and the contractor on the development status of the reliability products, problem areas, and additional clarification of the direction for Phase B activities. The formal reviews will support the scheduled program milestones (3, 6, 8, and 11 month of the Phase B contract).

   a. Reliability meetings will be conducted just prior to the major milestone reviews and will utilize formal minutes as a means to document agreements, action items, or areas of contention requiring management attention.

   b. The informal reviews will consist of special working sessions, joint telephone conversations, technical meetings, and conferences.

3. Development of a Phase C and D reliability approach: The reliability approach to be implemented during Phase C and Phase D of the Space Shuttle contract will be developed during the Phase B effort. This reliability program approach will reflect those unique requirements resulting from Space Shuttle studies in addition to those task definitions derived and based upon previous space programs experience. Reliability approach shall contain the following:

   Format
   Outline of Each Task
   Method of Accomplishing Task
   List of Supporting Documents

   a. The progress of the reliability approach shall be discussed with NASA at scheduled milestone reviews. Submittal of the reliability approach for Phase C and D will consist of a detailed briefing to the NASA at the end of the eighth month of the study effort.

   b. The basic approach to this effort will utilize NASA document NHB 5300.4(1A), plus other NASA documents to be furnished by MSFC on booster and MSC on orbiter. These documents are considered guidelines only and are not intended to restrain the pursuit of new and better approaches or innovations. In cases where the requirements deviate from these guideline documents, the difference will be identified and the associated rationale given.

WBS Number: 2.1.8
Integration Tasks (Cont)

4. Management Control: A management visibility and control system for both program implementation of reliability disciplines and the provision of communication records of inter- and intra-departmental reliability associated activities will be established. A control and feedback loop will be maintained to assure timely monitoring of both management visibility and control. Written communication between the Reliability Manager and other functional organizations will be implemented using the technique of internal letters, desk instructions, procedures, and other correspondence as applicable. These instructions will define the control and feedback system necessary for effective responses concerning reliability. Control for adherence in design to reliability disciplines will be accomplished through the study control process and the Engineering Review Board. Recommendations for reliability improvements will be documented as part of the study control process and submitted to the ERB prior to final system or subsystem selections. Where conflicts exist between reliability and other technical disciplines, these conflicts will be documented and submitted to the ERB for resolution. All related reliability documentation for this process will be available for customer review. An adequate reliability documentation system will be defined to avoid duplicate and untraceable documents concerning reliability.

   a. Monthly Project Progress Report will provide NASA with the significant reliability events occurring during the reporting period and the status of the scheduled milestones for the reliability tasks and products.

   b. Significant data generated during the study will be provided to NASA as completed, with progress being reported at the reliability review meetings.

WBS Number: 2.1.8
Integration Tasks (Cont)

Company:	Function:	Manager:
NR	Quality Assurance	L.B. Gray

5. Provide definition and coordination interface direction to Convair and the subcontractors to assure uniformity and compatibility of quality assurance criteria, documentation, and reporting to the customer. Significant data generated during the study will be provided to the NASA as completed with progress being reported at the quality assurance review meetings.

WBS Number: 2.1.8
Orbiter Tasks

Company:	Function:	Manager:
NR	Reliability	L.B. Gray

The following tasks will be performed to achieve the defined shuttle reliability objectives:

1. Criteria Implementation: The reliability criteria defined in integration task (1) will be imposed via the Systems Definition Handbook. A design checklist will be used as a means to assure that the defined areas were given consideration in the design trade-offs, concepts, and other related activities. These checklists will be available for review by the NASA throughout the program.

2. Implement Failure Mode Effects Analysis (FMEA) and Associated Activities: Functional level FMEA's will be conducted on contractor furnished flight equipment and that ground support equipment directly interfacing with the orbiter or booster during countdown. The FMEA shall be conducted in a top-down approach to the lowest level commensurate with the design. The FMEA shall include:

    a. A listing of all potential failure modes; failure mode cause; criticality of the failure mode; affected mission phase; failure effect on vehicle subsystem, related subsystems, and mission; failure detection method; alternate means of operation, and potential hazards.

WBS Number: 2.1.8
Orbiter Tasks (Cont)

b. A critical item list will be developed from the FMEA to include all Criticality 1, 1S, and 2A hardware, and hardware whose next failure will result in these categories.

3. Assessments and Trade Study Support: Reliability will participate in trade studies conducted on candidate designs. Special emphasis will be placed on development of efficient means of improving reliability by the use of alternate modes of operation, alternate functional concepts, and redundancy.

   a. The procedure developed under Integration Task 1b shall include a checklist to assure that all reliability concerns have been evaluated during the study. These checklists and analysis outputs will be provided to NASA.

   b. Reliability Numerical Estimates: Reliability numerical estimates will be limited to the support of trade studies and concept configuration selections where required and will be available for NASA review.

   c. Reliability will provide support to selected trade studies in those areas dealing with configuration selection which could affect orbiter reliability and crew personnel safety.

4. Technical Support and Program Documentation: NR Reliability will provide inputs to and review the following related program activities:

   a. Test Program: NR Reliability will provide inputs to and review the program test plan for subsequent implementation during Phases C and D. Special consideration shall be given to certification tests, subsystem and component acceptance tests.

   b. Specifications: NR Reliability will provide inputs to and review those documents to assure adequate controls and a common subsystem approach to the reliability disciplines.

   c. Abort Studies: Reliability inputs to the abort studies will consist of an identification of significant modes of failure which could result in mission termination and a subsequent review of the results of this study to ensure compatibility with the FMEA outputs.

   d. Reliability will provide inputs and review maintainability criteria to assure that reliability and maintainability is optimized.

WBS Number: 2.1.8
Orbiter Tasks (Cont)

5. Technology Studies: NR Reliability will provide a continuing effort in upgrading the technological approach to achieving the shuttle program objectives. Included in this task are:

   a. Supporting Technology: NR will participate in identifying and defining the technology which would enhance the space shuttle design or decrease development risks. Special consideration will be given to the following areas:

      EEE parts
      Reusability
      Limited life
      Redundancy techniques
      Test program (includes environmental acceptance)

   b. NASA-Supplied Technology: NR will review NASA supplied technology data and provide inputs to identified areas of technology advancement needs for the purpose of new technology and approaches. An assessment will be conducted on new technology approaches. These activities and assessments will be reviewed with the NASA.

Company:	Function:	Manager:
NR	Quality Assurance	L. B. Gray

6. Quality criteria.

   a. Develop quality criteria for baseline guidance to and usage by Quality Assurance in evaluating and providing recommendations during design analysis. These criteria will draw from experience gained from past aerospace and commercial aircraft development programs and will be updated throughout the Phase B activity as the engineering trade studies are refined and finalized. These criteria will be reflected in the final Phase B study program documentations, i.e., specifications, ICD's, and design drawings.

   b. Review applicable Phase B documentation prior to NASA submittal to assure that proper consideration has been given to quality requirements and criteria.

   c. Evaluate and document the company sponsored study to develop applications of special NDT techniques and inspections. Recommendations for their use will be submitted to Engineering for consideration in the design.

WBS Number: 2.1.8
Orbiter Tasks (Cont)

d. Provide availability to the NASA for all quality criteria developed during Phase B.

7. Design analysis.

a. Support Engineering in selected design concept trade studies with special emphasis on manufacturing requirements, design producibility, and test verification. Assure considerations of inspection, maintenance and repair criteria in the trade studies.

b. Provide consulting personnel to Engineering in specific areas as required and develop a quality checklist for use during Phase B reviews.

8. Quality Management Techniques (Phase C/D).

a. Develop recommendations and criteria for new approaches to quality assurance management in the areas of NDT, test and checkout surveillance, maintainability, turnaround inspection, and reuse, together with any additional advanced quality planning/management techniques developed during this phase. Provide special quality emphasis for advanced inspection planning on critical hardware.

b. Utilize recommendations and criteria together with NHB 5300.4(1B) and NASA supplied supporting documentation as a guide to develop a total quality approach for Phase C/D. Develop criteria and a design review checklist for use during Phase C/D. In cases where the requirements deviate from these guideline documents, the difference will be identified and the associated rationale given. This quality approach for Phase C/D will be presented to the NASA in the form of a briefing during the eighth month of the Phase B program.

c. Identify major quality cost drivers and develop methods of improved quality cost effectiveness for use in Phase C/D.

9. Manufacturing/Test Support

a. Support manufacturability studies by reviewing identified major manufacturing problem areas and develop recommendations for improvement.

WBS Number: 2.1.8
Orbiter Tasks (Cont)

b. Review identified facilities for shuttle manufacture, assembly, test, and operational checkout; and submit to program management any areas identified as potential problems by Quality Assurance.

c. Provide quality assurance review and inputs to the Test Plan, Facility Utilization and Manufacturing Plan, Logistics and Maintenance Plan, and Operations Plan in compliance with program documentation requirements.

10. Turnaround Inspection Techniques (Recycle)

a. Evaluate potential inspection problems during the maintenance turnaround cycle. Review the ground operations approach and identify any special inspection requirements. Assure that such requirements are considered in the design and trade study activity.

11. Quality Program Communications

a. Report the status of the tasks outlined above at informal reviews as well as through input to the monthly program progress reports and the program reviews conducted at the third, sixth, eighth, and eleventh months.

WBS Number: 3.1.8
Booster Tasks

Company:	Function:	Manager:
GD	Reliability	F. Lee

Tasks listed for orbiter will be performed relative to the booster.

WBS Number: 3.1.8
Booster Tasks

Company:	Function:	Manager:
GD	Quality Assurance	F. Lee

Quality tasks are identical to orbiter. Refer to paragraph 2.1.8 Quality for detail.

SPACE SHUTTLE PHASE B
TASK DESCRIPTION

WBS TITLE: MAINTAINABILITY

WBS Number: 2.1.9
Integration Tasks

Company:	Function:	Manager:
NR	Operations and Test	W. Edson

1. Direct and coordinate with Convair and American Airline for the conduct of specific maintainability studies affecting the space shuttle system, vehicle subsystems, and ground equipment. Emphasis will be placed upon identifying maintainability projects which can be performed by one group, thus, avoiding duplicate analysis.

2. Define and document system level maintainability requirements and criteria in the system specification and System Definition Handbook (SDH).

3. Provide direction to associate and subcontractors as necessary to assure compatibility between orbiter and booster maintenance concept. Direct preparation and coordination of the maintainability section of the Logistics and Maintenance plan (Task 4. 5. 6).

4. Develop and coordinate an overall maintainability evaluation program plan which will consider design reviews, verification tests, certification tests, and demonstration tests. This evaluation plan will be included as part of the logistics and maintenance plan; described in Task 4. 5. 6.

5. Provide representation to the ERB regarding system level maintainability criteria and requirements utilizing data prepared in support of trade studies and maintainability analyses.

WBS Number: 2.1.9
Integration Tasks (Cont)

Company:	Function:	Manager:
American Airlines	Maintainability	J. Amacker

6. Maintainability design criteria: Provide detailed listing of criteria for maintainability including accessibility, inspection and checkout techniques, replacement for minimum downtime, effect of all operational environment, and response to unscheduled maintenance.

7. Perform maintainability analyses in support of selected tradeoff studies.

8. Maintainability design consultation: Provide resident airline engineering representatives with experience in maintainability for design c consultation at SD and Convair.

9. Prepare and conduct a maintainability orientation course: To instruct design personnel on the maintainability objectives and design requirements for a Shuttle maintenance program, which can approach airline operational practice.

10. Operate a maintenance task sequence model covering the maintenance task cycles for the booster and orbiter and interpret results to NR and GD in terms of maintenance times and options.

WBS Number: 2.1.9
Orbiter Tasks

Company:	Function:	Manager:
NR	Operations and Test	W. Edson

11. Establish orbiter maintainability requirements which will assure design consideration for ease of refurbishment and maintenance and to realize short turnaround time during ground operations.

12. Perform a study of orbiter maintenance functions considering relevant factors such as: FMEA, logistics and maintenance capabilities, and checkout capabilities to determine progress toward attainment of maintainability goals. This study will be part of the support requirements analysis described in Task 2.1.3 and will be performed to the lowest equipment level consistent with design definition.

WBS Number: 2.1.9
Orbiter Tasks (Cont)

13. Provide detailed maintainability design criteria to be used in establishing hardware design.

14. Provide maintainability participation in design reviews and in determination of test plans for trade study evaluations. Downtime, accessibility, interchangeability, safety, and other factors which contribute to vehicle and system equipment availability will be considered. This criteria will be available for performing maintainability studies in support of design tradeoffs. Assess the time and logistics resources required to support alternative designs and document results in accordance with the Standard Evaluation Criteria and Methodology (Task 2.1).

WBS Number: 3.1.9
Booster Tasks

Company:	Function:	Manager:
GD	Logistics	A.H. Gross

1. The maintainability activity within the logistics function is intended to ensure that the booster hardware will contain design features that will permit operation of the system in its intended manner with a minimum expenditure of time and logistics resources. Basic booster maintainability tasks to accomplish this objective are:

    a. Establish quantitative and qualitative maintainability design criteria.

    b. Evaluate the evolving design to identify maintainability problem areas and provide support to design engineering in the resolution of these problems.

    c. Provide maintainability design requirements for inclusion in specifications.

    d. Participate in design tradeoff studies to provide maintainability consideration of proposed design approaches.

    . Participate in both informal and formal design reviews.

WBS Number: 3.1.9
Booster Tasks (Cont)

f. Conduct surveillance of vendor and subcontractor effort to ensure that required maintainability features are provided in their products and that appropriate maintenance data is supplied.

g. Provide inputs to program status reports, the logistics and maintenance plan, and the System Design Handbook.

SPACE SHUTTLE PHASE B
TASK DESCRIPTIONS

WBS TITLE: SELF-FERRY/GROUND HANDLING

WBS Number 2.1.10
Integration Tasks

Company:	Function:	Manager:
NR	Operations and Test	W. Edson

1. Define the combinations of orbiter and booster, as a function of the type turbojet and fuel to be studied.

2. Define for each combination of orbiter and booster elements of AAE and GSE that are common to the two vehicles; and define the final list of AAE and GSE required for ferry.

3. Define the payload to orbit (reference mission) capability of each of the vehicle combinations, accounting for any scar weight created by provision for ferry.

4. Define the total cost (RDT&E, Production and Operations) based on a 10 year operational program and parametrically varying the number and length of ferry flights for the orbiter and booster.

5. Based on the study results, recommend the desired type of turbojet fuel, AAE, GSE, manpower, and other support equipment required.

6. Define postflight safing requirements, on-board systems, GSE, and procedures to place the orbiter and booster in a safe condition following landing.

WBS Number: 2.1.10
Orbiter Tasks

Company:	Function:	Manager:
NR	Operations and Test	W. Edson

1. Define for the orbiter, the operations, personnel, ancillary equipment, ground support equipment, airports, transportation, and safety requirements necessary to perform the self-ferry mission of the orbiter from

WBS Number: 2.1.10
Orbiter Tasks (Cont)

the manufacturer's final assembly point to operational sites, from alternate landing sites to operational sites and between operational sites. Orbiter configurations to be studied will include combinations of the following:

a. High Cross-Range or Low Cross-Range Orbiter

b. Hydrogen Fueled Turbojet Engines

c. No Turbojet Engines

d. JP Fueled Turbojet Engines

- Low T/W long life
- High T/W short life

e. For a 25 flights per year or a 75 flights per year program, tasks to be performed are:

2. Define the specific combination from above to be investigated.

3. Define the maintenance and checkout requirements and flight safety as relevant to each engine and fuel combination.

4. Define the AVE (aerospace vehicle equipment) and AAE (aerospace ancillary equipment) that must be removed for ferry flights, if any.

5. Define the AAE, if any, that must be installed for ferry flights.

6. Define the ferry range capability as a function of 7, 8, and 9 above plus consumables such that the configuration does not exceed some defined maximum gross take-off weight (GTOW) and the allowable center-of-gravity (C.G.) limitations.

7. Define the consumables (hydrogen, oxygen, nitrogen, helium, etc.) required to service the orbiter for a ferry flight and to service the orbiter in post-flight (detanking, purging, etc.).

8. Define the logistics problem associated with delivery and handling of those consumables that are non-standard items at alternate and ferry landing fields.

WBS Number: 2.1.10
Orbiter Tasks (Cont)

9. Define the ground support equipment (GSE) required to provide for the removal of AAE (cargo containers, etc.), AVE, flight crew and or passengers, the installation of AAE, the landing or removed and installed equipment, and the servicing of the orbiter.

10. Define the required GSE, at alternate and ferry landing fields, that may be obtained as leased commercial equipment (e.g., mobile crane, etc.)

11. Define those operations required: (1) to initiate a ferry flight (from the manufacturing final assembly area and from a mission return alternate landing field), (2) at ferry intermediate fields, and (3) at the end of the ferry flight (normally at the operational site). (The operational site shall be considered as KSC, Florida for this trade study.)

12. Define the manpower (types and skills) required to perform the operations defined in (11) above.

13. Define transportation equipment required to deliver AAE (fuel tanks, engines, JATO's, etc.), GSE and flight and ground crew personnel to locations that are ferry flight initiation points (orbiter will be prepared for ferry flight).

14. Define transportation equipment required to deliver AAE (cargo containers, etc.), AVE (if any), GSE, orbiter passengers and flight crew, and ground crew personnel to the primary operations site. Required GSE and ground crew personnel may have to support intermediate stops of the orbiter.

WBS Number: 3.1.10
Booster Tasks

Company:	Function:	Manager:
GD	Operations	P.M. Prophett

1. For the booster, define operations, personnel, ancillary equipment, ground support equipment, airports, transportation, and safety requirements necessary to perform booster self-ferry missions from the manufacturer's final assembly point to operational sites and from

WBS Number: 3.1.10
Booster Tasks (Cont)

alternate landing sites to operational sites and between operational sites. The study will consider the following:

a. Straight wing and delta wing booster.

b. Hydrogen fueled air breathing engines.

c. JP fueled air breathing engines.

d. Flyback to launch site versus down-range landing based on operations site location.

e. Programs of 25 flights per year and 75 flights per year.

2. Specific tasks to be performed are:

a. Define maintenance, checkout and flight safety requirements related to various combinations of booster configuration, air breathing engine type and fuel selection.

b. Define the AVE (aerospace vehicle equipment) and AAE (aerospace ancillary equipment) that can be either removed or installed to accomplish ferry missions. Strap-on engines and/or fuel tanks will be considered.

c. Define ferry range capability as a function of Task 2 and 3, including consumables, such that the configuration does not exceed a specified maximum gross take-off weight or established center-of-gravity limitations.

d. Define the consumables (propellants and pressurants) required to service the booster in preparation for ferry flight and in post flight operations.

e. Define the GSE required for all servicing and maintenance tasks at alternate and ferry landing sites, including that required for removal or installation of AVE and AAE.

WBS Number: 3.1.10
Booster Tasks (Cont)

f. Coordinate company funded ground operations analysis study to define those operations required: 1) to initiate a ferry flight from the manufacturing and test location and/or a mission return to alternate landing site, 2) at ferry intermediate fields, and 3) at the conclusion of a ferry flight at the primary operational site.

g. Coordinate company funded support requirements analysis study which identifies and defines logistic support concepts for alternate and ferry landing sites. That study to include availability, lease or transportation of required GSE, consumables, and personnel by number, type, and skill level.

Company:	Function	Manager:
GD	Preliminary Design	R.A. Lynch

h. Provide vehicle design support to identify and define vehicle hard points compatible with ground handling requirements for ferry and ground operations necessary to support planned vehicle operations.

SPACE SHUTTLE PHASE B
TASK DESCRIPTIONS

WBS TITLE: GROUND AND FLIGHT SYSTEMS OPTIMIZATION

WBS Number: 2.1.11
Integration Tasks

Company:	Function:	Manager:
NR	Operations and Test	W. Edson

1. Investigate shuttle system requirements to provide definition of onboard functions, ground functions for checkout, launch control, guidance and navigation, and communications. Provide criteria for evaluating the onboard versus ground options and recommend extent of vehicle autonomy for ground and flight system optimization study.

   Specific tasks are:

   a. Define combinations of orbiters and boosters, as a function of the autonomous vehicle capability relative to checkout, guidance and navigation, docking, and landing.

   b. Define the supporting systems, ground and satellite, required with the combinations defined in a. above.

   c. Define the payload capability and total program cost associated with each combination defined in a. above.

   d. Prepare a matrix that displays the information so a specific combination can be recommended.

2. Define developmental and qualification flight phase test and checkout and support requirements and determine how to implement the requirements with least program cost impact.

WBS Number: 2.1.11
Orbiter Tasks

Function:
Operations and Test

Manager:
W. Edson

1. Determine onboard performance monitoring and operational readiness verification requirements. Identify safety-critical function monitoring requirements and priorities, onboard monitoring requirements for other functions, and functions critical to ability to meet turnaround and fast-reaction launch requirements. Assign priorities to these functions. Define functional requirements to support turnaround and prelaunch checkout. Establish functional GSE requirements to perform ground checkout functions. Define GSE hardware costs, manpower costs, onboard checkout hardware cost, checkout time, vehicle weight, other costs (spares, design, etc.), and software costs as a function of degree of onboard checkout capability.

2. Define vehicle launch control location requirements, i.e., onboard versus ground. Identify vehicle launch control functional requirements and identify and recommend launch control location.

3. Evaluate satellite communications system requirements to provide operational and other tradeoff data for the synchronous satellite system, ground communications network, and combinations of both.

4. Provide criteria to support the evaluation and optimization of onboard versus ground checkout equipment. Define timelines and test personnel requirements for their influence on the design and selection of the onboard checkout system baseline. Evaluate the baseline checkout system for acceptance checkout of the operational vehicle as well as the optimum integration of the onboard checkout system upstream into the development and qualification test program.

5. Conduct a safety analysis of the vehicle-imposed requirements on ground systems, consideration of the effects of these requirements on the safety of ground support personnel, crew and passengers, GSE, and other launch equipments. Assemble safety requirements for vehicle and ground systems. Identify potential and inherent hazards in the above effort, associated with onboard checkout equipment, or lack of such equipment. Provide description of the identified hazards, documented on-hazard analysis sheet in support of system safety engineering.

Company:	Function:	Manager:
NR	Integrated Electronics	G.C. Anderson

6. Define orbiter vehicle requirements by providing definition of onboard and ground functions for checkout, launch control, guidance and navigation, and communications.

7. Define ground system functional requirement to support G&N mission requirements. Identify degree of autonomy of G&N (other than maintenance or checkout).

8. Establish recommended satellite communications requirements. Define shuttle data transfer and voice communications requirements.

Company:	Function:	Manager:
NR	Avionics	C.E. Grunsky

1. Participate in a ground and flight systems optimization trade study to analyze the requirements the booster vehicle imposes on ground systems and to determine the functions to be handled totally onboard and what the implications are between increased requirements on vehicle versus increased complexity and cost of ground operations.

2. Participate in a booster, orbiter, and space station subsystem-and-equipment common usage trade study to define the extent to which orbiter and space station subsystem designs are compatible with booster requirements and constraints. This task will include:

   a. The areas in which the booster should have an active part in checkout and launch control functions will be determined.

   b. Criteria for the degree of effect a failure has on the booster capability to perform a mission will be established.

   c. The definition of the impact on the onboard checkout system on the ability of the booster to satisfy the required turnaround and fast-reaction launch times will be assessed. This will provide priorities and potential usage for onboard checkout requirements and will include the ground-checkout and fault-isolation modes.

   d. Ground checkout requirements identification.

   e. An analysis will be conducted to identify the best means of satisfying these requirements.

SPACE SHUTTLE PHASE B
TASK DESCRIPTIONS

WBS TITLE: PAYLOAD INTEGRATION

WBS Number: 2.1.12
Integration Tasks

Company:	Function:	Manager:
NR	System Engineering	J. Bates

1. Review available data from the Space Station Program for typical payloads required in the baseline logistics mission. Define candidate payloads and payload mixes for baseline design purposes. Review available data on alternate missions and select candidate payloads for consideration in shuttle system design. Included are the identification and classification of hazards associated with types of cargo, and loading and unloading of cargo both on the ground and in space.

2. For the payload ground handling modes under consideration, establish payload interface requirements. These requirements will be established for the baseline logistics mission payloads and a second group will be structured considering alternate mission payloads.

3. Define the physical and operational interfaces between the payload module, space station, and orbiter vehicle. Define an initial operational mode for the transfer of cargo and passengers in space for use in developing the baseline design.

WBS Number: 2.1.12
Orbiter Tasks

Company:	Function	Manager:
NR	System Engineering	J. Bates

1. Define interface requirements for installation of typical space station logistics mission payloads. Define requirements for the deployment and retrieval of alternate payloads including the provisions for space orientation updating.

WBS Number: 2.1.12
Orbiter Tasks (Cont)

2. Prepare and update orbiter payload integration data as required for use in preliminary test plan, logistics development and facility plans, CEI specifications and Systems Definition Handbook.

3. Evaluate and document the results of the company sponsored Payload Deployment and Retrieval trade study for application to the contract effort. This trade study includes:

    a. Analysis of selected candidate payloads.

    b. Concept formulation of selected payload deployment and retrieval systems.

    c. Development of an evaluation and selection criteria.

    d. Qualitative analysis as to the impact on the shuttle baseline design required to incorporate the candidate payload deployment and retrieval systems concept.

    e. Review and analysis of data developed in the following associated trade studies to provide guidelines in the formulation of concepts:

        a. Ground and Flight System Optimization
        b. Space Station Docking and Stabilization Methods
        c. On-board Checkout Techniques
        d. Vehicle Alternate Mission Capability.

4. Evaluate and document the results of the company sponsored Passenger and Cargo Transfer in Space trade study for application to the contract effort. This trade study includes:

    a. Analysis of the shuttle and station interface.

    b. Review and evaluation of the space station docking and stabilization trade study data.

    c. Formulation of an evaluation criteria.

    d. Review of applicable data derived from shuttle trade studies on:

        (1) Cargo Storables Loading and Unloading.
        (2) Integral Passenger Cabin Versus Cargo Bay Personnel Module.
        (3) Space Thermal Control Concepts.
        (4) Ground and Flight System Optimization

WBS Number: 2.1.12
Orbiter Tasks (Cont)

5. Evaluate and document company sponsored study on Shuttle-to-Payload Information for application to the contract effort. This trade study includes:

   a. Analysis of shuttle payload interface.

   b. Review and evaluation of data developed in the ground and flight systems optimization trade study.

   c. Review and evaluation of data derived from the on-board checkout technique trade study.

   d. Review of alternate mission payloads defined in vehicle alternate mission capability study.

6. Compile the results of the payload integration study for a final report input.

Company:	Function:	Manager:
NR	Project Engineering	G.F. Fraser

7. In company sponsored activities schedule and direct meetings between the Shuttle and Space Station working groups to define shuttle design criteria and shuttle system, space station, and payload interface requirements. Ensure recommended shuttle, space station, experiment modules, unmanned satellites, and ground facilities interface criteria and requirements are reviewed with NASA to obtain concurrence.

8. In company sponsored activities schedule and direct meetings with NASA to obtain results of advanced technology study for handling of cargo and expendables for space shuttle system. Ensure that these study results are used in space shuttle design.

9. Review approach and subtasks for trades of passenger and cargo transfer in space.

10. Ensure results of final payload integration studies are reported to NASA.

WBS Number: 2.1.12
Orbiter Tasks (Cont)

Company:	Function:	Manager:
NR	Preliminary Design	W.A. Martin

11. Define, in the form of preliminary design layouts, the means for payload installation, packaging, deployment, handling and cargo, and crew transfer as it applied to the orbiter vehicles of the space shuttle system in its execution of space missions. The design data will support the mission analysis and interface definition for the orbiter-payload combination.

Company:	Function:	Manager:
American Airlines	Payload Integration	J. Amacker

12. Provide assistance to NR and GD in the identification of cargo loading and unloading equipment, including equipment requirements for the airborne vehicles.

SPACE SHUTTLE PHASE B
TASK DESCRIPTIONS

WBS TITLE: UNMANNED VERSUS MANNED BOOSTER

WBS Number: 3.1.12
System Analysis

Company:	Function:	Manager:
GD	System Integration	H. M. Bonesteel

1. Conduct an unmanned-versus-manned booster trade study which will include consideration of reliability of booster recovery, complexity and over-all effectiveness of automatic-or ground-controlled unmanned configurations, and safety and complexity of manned configurations. These considerations shall be applicable to abort, ferry-flight and normal-launch phases. Manned operations requirements shall be determined and evaluated. Prepare and submit a trade study report.

2. Define crew operations for normal and ferry missions as derived from mission requirements, abort procedures, flight characteristics and from the integrated display-and-controls study. Define extent of subsystem management, corrective action capability and emergencies requiring decision-making capability. Analyze unmanned operational concepts for normal and ferry missions, considering available landing fields, abort procedures, government regulations, and emergency procedures.

3. Identify baseline ground-control capability and possible changes required. Define electronics system changes and ground-equipment interface requirements. Evaluate effectiveness of automatic controls and sensors and integrated concepts for automated subsystems.

4. Examine redundancies; operational flexibility; and on-board displays, controls, communications and furnishings required for both manned and unmanned concepts. Determine probability of booster recovery for manned versus unmanned mode, and identify the effect on equipment commonality between booster and orbiter.

5. Provide interface requirements for unmanned booster. Provide input on GSE and facilities design to accommodate unmanned booster.

WBS Number: 3.1.12
System Analysis (Cont)

6. Assist in system operations analysis (using system operations model) to determine the relationship between unit system design and operational performance characteristics and the numbers of units required to accomplish the specified mission requirements (i.e., launch rate, vehicle inventories, numbers of facilities, personnel).

7. Coordinate and direct specific point design cost estimation studies which include division estimating, manufacturing, test, and operations activities.

8. Estimate total program costs for each operational site.

9. Provide trajectory analysis, synthesis program, and aerodynamic support if required due to major difference.

SPACE SHUTTLE PHASE B
TASK DESCRIPTIONS

WBS TITLE: VEHICLE DESIGN ANALYSIS

WBS Number: 2.2.1
Integration Tasks

Company:	Function:	Manager:
NR	Preliminary Design	W.A. Martin

1. Evaluate and document company sponsored orbiter-on-booster position studies for application to shuttle vehicle. These studies include:

   a. Orbiter position on booster, including fore and aft location and angle-of-attack.

   b. Structural arrangement consideration of orbiter and booster.

   c. Aerodynamic interferences.

   d. "q" versus load history.

2. Provide GD layouts and data to support booster design and analysis.

3. Evaluate and document GD booster design for effect on orbiter design.

4. Prepare mated vehicle layouts showing general arrangement and dimensions.

WBS Number: 2.2.1
Orbiter Tasks

Company:	Function:	Manager:
NR	Preliminary Design	W.A. Martin

1. Prepare preliminary design sketches and layouts for the orbiter high-cross-range and low-cross-range baseline configurations (including configurations of a straight-wing versus delta-wing orbiter for low cross range) to define overall orbiter vehicle designs, including aerodynamic shape characteristics, propellant tankage details and arrangement, the

WBS Number: 2.2.1
Orbiter Tasks (Cont)

location and dimensional requirements for major components and subsystems, the limits of crew visibility in normal flight docking and landing attitudes, the arrangement and space allocation for the crew and passengers, preliminary details of the airborne structure, and general arrangement and three-view drawings for the orbiter vehicle configurations. A preliminary hazard analysis will be conducted on structural elements and critical systems.

Company:	Function:	Manager:
NR	Flight Technology	N.F. Witte

2. Determine all vehicle dimensional criteria as related to aerodynamic performance and stability requirements. Support propellant distribution and size trade. Define effects of geometry variations on aero characteristics of orbiter to support subsystem trades.

Company:	Function:	Manager:
NR	Fluids and Propulsion	R.E. Fields

3. Provide engine and system design concept, sizes, and configuration at major subsystem components to support vehicle layout and arrangement type drawings.

WBS Number: 3.2.1
Booster Tasks

Company:	Function:	Manager:
GD	Preliminary Design	R.A. Lynch

1. Prepare preliminary design layouts for the booster to define overall vehicle designs, including aerodynamic shape, propellant tankage and engine arrangements, and arrangements for major components and subsystems. Specifically:

   a. Support NR in the creation and updating of baseline vehicles.

   b. Conduct miscellaneous booster design improvement studies.

   c. Conduct a delta and stowed wing versus straight wing booster trade study.

WBS Number: 3.2.1
Booster Tasks (Cont)

Company:	Function:	Manager:
GD	Flight Technology	S. Starr

2. Determine all vehicle dimensional data as related to aerodynamic performance and stability requirements. Provide support to delta-wing and stowed-wing trade study.

Company:	Function:	Manager:
GD	Structure and TPS	F. Krohn

3. Provide preliminary structure and TPS arrangements in support of overall vehicle arrangement and weights.

SPACE SHUTTLE PHASE B
TASK DESCRIPTIONS

WBS TITLE: STRUCTURES

WBS Number: 2.2.2
Integration Tasks

Company:	Function:	Manager:
NR	Vehicle Structures	R. A. Lusk

1. Develop mathematical models for mated configuration, determine stiffnesses, and calculate modes.

   a. Formulate mathematical models for selected design conditions including prelaunch, liftoff, max $q\alpha$, end boost, and separation. Calculate stiffnesses for mated vehicles and substructure such as surfaces, thrust structure, tanks, etc.

   b. Calculate vibration modes and frequencies of mated vehicles and of key substructure elements.

2. Calculate mated vehicle response and loads.

   a. Determine preliminary loads (rigid body) for various sizing and trade studies; such as first stage acceleration, abort, orbiter position on booster, control system definition, etc.

   b. Determine preliminary vehicle loads for key design points, such as max $q\alpha$ and end boost.

   c. Determine final vehicle loads including flexibility effects for total vehicle and/or local structural response to transient excitations and steady-state aerodynamic forces. Consider inputs due to max $q\alpha$, gust/buffet excitation, flight control commands, end boost, and separation.

   d. Provide response/loads support to system development including TPS, separation, flight control, etc.

WBS Number: 2.2.2
Integration Tasks (Cont)

Note: Trajectory analyses for winds and separation - see WBS 2.1.5.

3. Conduct aeroelastic and other structural dynamic stability studies.

   a. Analyze mated vehicles for flutter over typical boost phase mission profile using cantilever surface models.

   b. Perform static aeroelastic analysis including divergence, lift effectiveness, and control reversal/effectiveness studies for mated vehicles.

4. Predict/calculate shock, vibration, and acoustic environments and develop design and test criteria.

   a. Make preliminary estimates of aero-acoustic noise for boost flight phases.

5. Provide coordination in structural dynamics.

   a. Visit NASA research centers to obtain current test data pertinent to shuttle structural problem areas associated with mated vehicles.

   b. Prepare necessary plans, attend GD/C - NR/SD coordination meetings, and coordinate details of integration task structural dynamics.

WBS Number: 2.2.2
Orbiter Tasks

Company:	Function:	Manager:
NR	Vehicle Structures	R. A. Lusk

1. Develop mathematical models, determine stiffnesses, and calculate modes.

WBS Number 2.2.2
Orbiter Tasks (Cont)

a. Formulate mathematical models for selected design conditions, including docking, entry/transition, cruise/ferry, and landing. Calculate stiffnesses for orbiter and substructure; such as surfaces, thrust structure, tanks, landing gear, etc.

b. Calculate vibration modes and frequencies of orbiter vehicle and of key substructure elements. Include axial modes for POGO studies.

c. Calculate slosh modes/frequencies for vehicle stability analyses.

2. Calculate vehicle response and loads.

a. Determine preliminary loads (rigid body) for various sizing and trade studies; such as abort, entry transition mode, control system definition, landing gear development, engine deployment, docking impact, tankage concepts, etc.

b. Determine preliminary vehicle loads for key design points, such as prelaunch, docking, and landing, and for maneuver/buffet/gust response during entry and transition to cruise.

c. Determine final vehicle loads including flexibility effects for total vehicle and/or local structural response to transient excitations and steady-state aerodynamic forces. Consider inputs due to docking, maneuver, buffet and gust response during entry and cruise, and landing impact and taxi.

d. Provide response/loads support to system development, including ground handling and ferrying, TPS, docking, landing, flight control propulsion, etc.

3. Conduct aeroelastic and other structural dynamic stability studies.

a. Analyze orbiter vehicles for lifting and control surface flutter over typical mission profile using cantilever surface models.

b. Evaluate potential stall flutter/buffet problem.

WBS Number 2.2.2
Orbiter Tasks (Cont)

c. Conduct panel flutter studies of TPS panels and other key structural surfaces for entire mission profile.

d. Perform static aeroelastic analysis including divergence, lift effectiveness, and control reversal/effectiveness studies.

e. Conduct preliminary study to assess possible POGO instability, using available models of tanks and thrust structure, feedline/pump/ engine transfer functions, and vehicle axial modes.

4. Predict/calculate shock, vibration, and acoustic environments and develop design and test criteria.

a. Make preliminary estimates of acoustic environments due to engine noise (rocket and jet) and aero-acoustic noise for orbiter-alone flight phases.

b. Make predictions of all vibration and shock environments for all mission phases.

c. Perform sonic fatigue analysis of secondary structural regions and TPS panels (metallic and nonmetallic).

5. Provide management/administrative direction in structural dynamics.

a. Prepare overall logic plan and schedule, and support planning exercises (work packages, study plans, support research and technology plans, etc.).

b. Attend NASA/industry working group meetings and support internal meetings, such as ERB's, design reviews, and staff meetings.

c. Visit NASA research centers to obtain current test data pertinent to shuttle structural dynamics problem areas, specifically buffet, flutter, and ground winds.

6. Evaluate and document the results of company-sponsored studies for application to the contract effort. These studies include load studies for determination of structural integrity and weights of orbiter

WBS Number: 2.2.2
Orbiter Tasks (Cont)

spacecraft, boosters, and entry vehicles. This covers the area of mathematical modeling, modal analysis, loads aeroelasticity, vibration, and acoustics.

a. Compile boost, entry, and landing configuration stiffness data and develop mathematical models for various structural configurations. Identify critical parameters and their effect on vehicle stiffness and mass matrices.

b. Generate mode shapes and frequencies and external body loads for selected configurations identified in Task 6a.

   (1) Calculate rigid body loads of configurations for use as a base from which to generate flexible body loads.

   (2) Calculate simplified 3-D modes for high-q maximum acceleration load regimes. Investigate POGO effects at selected times.

c. Determine buffet, flutter and static aeroelastic characteristics of typical boost and entry vehicles. Identify any potential aerothermo elastic problems inherent in winged entry vehicles.

   (1) Perform buffet, flutter, and static aeroelastic trade studies of selected configurations of boost and entry vehicles.

   (2) Determine buffet, flutter, and static aeroelastic loads.

   (3) Define aerodynamic noise environment ranges and evaluate potential sonic fatigue problems associated with these configurations.

   (4) Estimate vehicle vibration response and determine structural vibration loads.

   (5) Identify areas that require additional verification and plan wind tunnel tests program to verify these using wind tunnel facilities.

WBS Number: 2.2.2
Orbiter Tasks (Cont)

7. Conduct structural analysis on the shuttle airframe, TPS, and pressure vessels.

   a. Identify critical combination of pressure, temperature, and load for two orbiter configurations. Select materials and define size and shape of structural components.

   b. Perform preliminary structural analysis of two orbiter vehicles, based on preliminary design drawings and loads. Depth of analysis will be adequate to substantiate weight estimates and establish concept feasibility.

   c. Identify structural components for which structural testing is required to substantiate analysis.

   d. Document structural analyses and compile results of applicable related studies for inclusion in Structures and Materials report.

8. Provide structural analysis support to the following system development and definition:

   a. Cost Analysis 4.8: Provide material size and shape definition in support of cost analysis.

   b. Self Ferry and Ground Handling 2.1.10: Evaluate transportation and handling loads. Compare structural requirements with those for the design mission. Identify requirements which exceed design mission requirements and restrictions required to prevent structural degradation or damage.

   c. Vehicle Design 2.2.1: Provide recommended structural concepts, results of structural arrangement trades, and structural size and shape requirements.

   d. Mass Properties 2.2.5: Provide structural sizes and shapes for airframe, TPS, and pressure vessels.

WBS Number: 2.2.2
Orbiter Tasks (Cont)

e. Landing System 2.3.3: Provide structural analysis support to the mechanical landing system as follows:

(1) Select materials and define selection rationale.

(2) Provide required areas for structural members.

(3) Evaluate requirements for proof tests of landing system.

f. Docking System 2.3.4: Coordinate and assure integration of the structural requirements of size, stiffness, geometry, and material properties into the docking mechanism, docking ports, and surrounding structure defined by the structural analysis.

g. Preliminary Design Drawing 2.4.2: Provide recommended structural concepts, results of structural arrangement trades, and structural size and shape requirements.

h. Preliminary Specifications 2.4.5: Review the performance and design requirements specifications to assure that vehicle structures requirements are specified and provide design data.

i. Preliminary ICD's 2.4.4: Review the structural oriented physical, functional and procedural ICD's to assure vehicle structures requirements are specified.

j. Mockups and Models 2.4.3: Provide structural requirements for mockups and models.

9. Evaluate and document the results of company-sponsored studies for application to the contract effort. These studies include:

a. Identify structural concepts incorporating minimum weight and cost effectiveness characteristics.

b. Conduct meteoroid shielding analysis. Establish allowable damage for structural components, apply penetration mechanics for single and multisheet structures, and define probability of meteoroid damage in excess of established allowable limits.

WBS Number: 2.2.2
Orbiter Tasks (Cont)

c. Conduct internal structural arrangement trades, giving consideration to tankage shape and support, cargo support and access, thrust structure, vehicle attachment, and wing carry-through. Evaluate on a strength/weight basis the applicability of various stiffened skin and advanced composite types of construction. Prepare rationale for arrangement and construction selection.

d. Prepare a structural integrity plan which indicates the approach by which structural analyses and tests will be used to provide the confidence in structural integrity required for man rated reusable space vehicles.

e. Identify areas requiring structural test verification and prepare test plan.

f. Perform structural analyses required to evaluate various systems and subsystems as listed in the following:

(1) Safety - Identify and classify potential and inherent hazards relating to the crash-worthiness of entry vehicles.

(2) Alternate Missions - Evaluate vehicle body loads for selected alternate missions. Identify extent to which nominal mission loads are exceeded. Evaluate the effect of alternate mission loads and temperatures on the airframe; pressure vessels.

(3) Reliability - Identify structural failure modes for failure modes and effects analysis (FMEA's).

(4) Propulsion Systems - Provide recommended structural concepts and structural size requirements for pressure vessels associated with the main propulsion, attitude control propulsion, orbit maneuver, airbreathing, and cryogenic tankage systems.

(5) Vehicle Mating/Transportation Erection/Servicing - Evaluate vehicle body loads resulting from various mating, transportation, and erection concepts in support of subject trade study. Identify restrictions which must be imposed to prevent body loads in excess of mission design loads.

(6) Power Systems - Provide recommended structural concepts and structural size and shape requirements for fuel cell pressure vessels.

WBS Number: 2.2.2
Orbiter Tasks (Cont)

(7) Electromechanical and Integrated Avionics - Provide structural size and construction requirements in support of radome/antenna development and definition.

g. Perform thermo-structural trade studies and tests to define methods of providing a reusable thermal protection system for entry vehicles and hypersonic aircraft. Define design concepts, perform analytical evaluation of design, and verify by test.

Perform TPS tradeoffs, varying concepts, constructions, and materials. Consider hot structure, radiative insulation, ceramics, impregnated refractories, graphite, unprotected insulative systems, active and transpiration cooled systems. Evaluate concepts on a weight-volume-cost basis.

Fabricate and test selected structural concepts, including metallic radiative heat shields and hot structure concepts.

h. Evaluate advanced composite design concepts for use in space shuttle applications. Generate strength/weight tradeoff data for advanced composites versus more conventional construction and materials.

WBS Number 2.2.2
Orbiter Tasks (Cont)

Company:	Function:	Manager:
NR	Flight Technology	N. F. Witte

10. Issue orbiter rigid-body airloads and pressure distribution data through the Airloads Design Data Book at specified flight conditions. Data will be based on theoretical estimates and analysis of wind tunnel results obtained in WBS 2.1.5.

11. Evaluate results of company sponsored loads and environment studies for application to the contract. This effort includes:

   a. Definition of preliminary airloads for entry, transition, and landing conditions.

   b. Definitions of venting requirements and compartment pressures for structural analysis during entry conditions.

WBS Number: 2.2.2
Orbiter Tasks (Cont)

12. Provide support to the integration tasks by the following activities:

    a. Evaluate results of company-sponsored studies in order to establish preliminary airloads for the baseline integrated vehicles at critical design conditions.

    b. Determine distributed and component airloads for specified orbiter/booster positions and alignments to support orbiter position on booster trade study.

    c. Issue airloads and pressure distribution data through the Airloads Design Data Book at specified flight conditions, assuming a rigid body and using wind tunnel results from WBS 2.1.5.

    d. Evaluate and document the results of company-sponsored studies for application to the contract effort. These tasks include:

        (1) Define parametric airloads data as affected by geometry, orbiter and booster position, and flight condition.

        (2) Define compartment venting requirements and pressures during ascent.

WBS Number: 3.2.2
Booster Tasks

Company:	Function:	Manager:
GD	Flight Technology	S. Starr

1. Develop mathematical models, determine stiffnesses, and calculate modes.

    a. Formulate mathematical models for selected design conditions, including entry/transition, cruise/ferry, and landing. Calculate stiffnesses for booster and substructure; such as surfaces, thrust structure, tanks, landing gear, etc.

    b. Calculate vibration modes and frequencies of booster vehicle and/or key substructure elements.

    c. Calculate slosh modes/frequencies for booster stability analyses to support abort studies.

WBS Number: 3.2.2
Booster Tasks (Cont)

2. Calculate vehicle response and loads.

   a. Determine preliminary loads (rigid body) for various sizing and trade studies; such as abort, entry transition mode, control system definition, landing gear development, engine deployment, and tankage concepts.

   b. Determine preliminary vehicle loads for key design points, such as maneuver and gust for entry and/or transition to cruise, landing, etc.

   c. Determine final vehicle loads including flexibility effects for total vehicle and/or local structural response to transient excitations and steady-state aerodynamic forces. Consider inputs due to maneuver, buffet and gust for entry and cruise and landing impact and taxi.

   d. Provide response/loads support to system development, including ground handling and ferrying, TPS, landing, flight control, propulsion, etc.

3. Conduct aeroelastic and other structural dynamic stability studies.

   a. Analyze booster vehicle for lifting and control surface flutter over typical mission profile using cantilever surface models.

   b. Conduct panel flutter studies of TPS panels and other key structural surfaces for the entire mission profile.

   c. Perform static aeroelastic analysis, including divergence, lift effectiveness, and control reversal/effectiveness studies.

4. Predict/calculate shock, vibration, and acoustic environments and develop design and test criteria.

   a. Make preliminary estimates of acoustic environments due to jet engine noise and aero-acoustic noise for booster-alone flight phases.

   b. Make predictions of all vibration and shock environments.

   c. Perform sonic fatigue analysis of secondary structural regions and TPS panels (metallic and nonmetallic).

WBS Number: 3.2.2
Booster Tasks (Cont)

5. Provide coordination in structural dynamics.

   a. Prepare overall logic plan and schedule and support planning exercises (work packages, study plans, support research and technology plans, etc.).

   b. Attend GD/C - NR/SD coordination and NASA/industry working group meetings and support internal meetings, such as ERB's, design reviews, and staff meetings.

   c. Visit NASA research centers to obtain current test data pertinent to shuttle structural dynamics problem areas, specifically buffet, flutter, and ground winds.

6. Provide support to the integration tasks by the following activities:

   a. Formulating mathematical model of booster for selected design conditions including prelaunch, liftoff, max α q, end boost and separation.

   b. Provide control system characteristics.

   c. Provide booster alone aero data.

   d. Determining prelaunch and liftoff external loads.

   e. Determining separation loads.

   f. Conducting preliminary study to assess possible POGO instability, using available models of tanks and thrust structure, feedline/pump/engine transfer functions and vehicle axial modes.

Company:	Function:	Manager:
GD	Structure and TPS	F. Krohn

7. Define structural design criteria. Periodically review and update as required.

WBS Number: 3.2.2
Booster Tasks (Cont)

8. Support vehicle configuration tradeoff studies listed in WBS 2.2.1 by providing a definition of the structural systems applicable to a straight-wing, a delta-wing, and a stowed-wing configuration. Assist in structural sizing to determine structure weight coefficients for input to the vehicle synthesis program. Provide an assessment of structural characteristics to facilitate vehicle configuration evaluation.

9. Support the orbiter-position-on-booster trade study by determination of the impact on booster structural weight due to differences in structural response and orbiter attachment locations.

10. Support the thermostructural trade studies listed in WBS 3.2.4.

11. Perform structural tradeoff studies:

    a. Propellant tank materials.

    b. Aluminum versus titanium for the inter-tank structure and structure forward of the propellant tanks.

    c. Integrally stiffened versus multi-spar wing and stabilizers. Assess the tradeoff candidates on the basis of low weight, low cost, technology status, reliability, and amenability to inspection and repair.

    d. Composites application to thrust structure.

    e. Composites application to wing, MLG, and interstage support structure.

    f. Prepare a master overall structural arrangement drawing of the selected structural/TPS concept.

    g. Prepare detail layouts of each major structural component.

    h. Define fabrication techniques and assembly methods applicable to each major component of the primary structure.

    i. Perform design investigations of the structural configurations, with consideration of fabrication techniques, to determine nonoptimum factors for inclusion in structural weight estimates.

WBS Number 3.2.2
Booster Tasks (Cont)

*j. Design and test structural element test specimens for substantiation of analysis and to assist verification of structural weight estimates.

k. Provide preliminary design drawing of each major structural component.

l. Conduct structural analysis of a selected booster airframe, TPS, and propellant tank arrangement.

(1) Identify the critical design load and structural temperature combinations, net external loads, and internal loads which design the vehicle structure.

(2) Perform preliminary structural anaysis and sizing of the principle structural elements based on preliminary design layouts and material selections. Depth of analysis will be adequate to establish design concept feasibility and to provide substantiation of weight estimates.

(3) Establish load and temperature spectra representing the vehicle service life and conditions, and calculate the safelife of critical tension loaded structural elements. Classical fatigue analysis methods and fracture mechanics methods assuming pre-existing flaws will be used. Establish guidelines to provide damage tolerance and fracture control with the least impact on structural weight.

(4) Identify the structural components for which structural element tests are required to verify design allowables, analysis methods, and unusual design details. Evaluate the results of the structural element test program and its impact on the vehicle structure and mass fraction.

(5) Perform thermal stress and deflection analysis of the thermal protection system and/or hot structures. These stresses and deflections will be combined with those from primary flight loads. Net stress and deflections will be established to evaluate thermal fatigue, creep, and thermal buckling problems.

(6) Document the structural analysis and results for inclusion in the Structures and Materials reports.

*Company sponsored.

WBS Number 3.2.2
Booster Tasks (Cont)

12. Provide structural analysis support of configuration, structural concept, and material trade studies.

    a. Perform structural analysis and sizing in support of weight estimates and trade studies of (1) alternate vehicle external configurations (2) alternate structural concepts and TPS systems, and (3) alternate design materials.

    b. Perform loads, structural analysis, and structural sizing in support of trade studies to determine the attachment criteria of the orbiter to the booster. These investigations will include location, attachment and separation schemes, and the effect of the orbiter rocket exhaust on the booster body and tail structure.

    c. Support the investigation for applications of advanced composite materials with high weight payoffs and cost effectiveness.

    d. Investigate fail-safe design concepts for propellant tank and wing box structures to provide fracture control. Determine their effect on vehicle weight and the fracture control guidelines.

13. Provide structural analysis support of the following systems development and definition:

    a. Preliminary specifications. Review the design criteria specifications to assure that vehicle structural design criteria are clearly defined and interpreted. Establish the necessary detail structural design criteria such as special factors and deflection limits.

    b. Vehicle design. Provide recommended structural component shapes and sizes and structural concepts for minimum structural weight.

    c. Mass properties. Determine structural sizes and theoretical weights of the principal structural elements to verify the structural mass fractions.

    d. Stiffness properties. Provide preliminary stiffness data of the primary structure components in support of flight loads, dynamic loads, and flutter analysis. Also provide local panel stiffnesses for sonic fatigue and panel flutter evaluations.

WBS Number: 3.2.2
Booster Tasks (Cont)

**14. Evaluate and document the results of company-sponsored studies for application to contract effort. These studies include:

a. Structural synthesis programs for station-by-station structural sizing of the body, wing, and fin. These programs will provide rapid evaluation of alternate design concepts, materials, and shapes.

b. Investigation of the effects of thermal stresses, thermal buckling, high temperature fatigue, and creep on TPS concepts and hot structural components.

c. The development of composite structure analysis methods to provide minimum weight composite laminate, composite reinforced frame, and composite tubular column design.

**Company-funded tasks.

SPACE SHUTTLE PHASE B
TASK DESCRIPTIONS

WBS TITLE: MATERIALS

WBS Number: 2.2.3
Integration Tasks

Company:	Function:	Manager:
NR	Vehicle Structures	R. A. Lusk

1. Provide an exchange of materials data between NR/SD and GD/C.
    a. Coordinate test program plans.
    b. Exchange data from the test programs.
    c. Exchange pertinent data from past test programs.
2. Maintain compatibility of engineering philosophy between NR/SD and GD/C for:
    a. Materials selection.
    b. Allowables and materials properties.
    c. Fracture control.
    d. Flammability, toxicity, and outgassing of materials.

WBS Number: 2.2.3
Orbiter Tasks

Company:	Function:	Manager:
NR	Vehicle Structures	R. A. Lusk

1. Issue a preliminary design data book based on past and present test programs and literature surveys.
2. Evaluate producibility of structural or systems design concepts required to support shuttle.
3. Define development programs for materials or processes required to support Shuttle during Phase C/D.

WBS Number: 2.2.3
Orbiter Tasks (Cont)

4. Provide support to Shuttle Engineering in selection of materials and processes and in trade studies.

5. Evaluate and document the results of the company-sponsored materials studies for application to the contract effort. These studies include:

    a. Establish material design properties applicable to TPS, tanks, structures, etc.

        (1) Collect and analyze published data for pertinent materials.

        (2) Outline tests required to supplement published data.

        (3) Conduct tests of selected materials identified in 5a(2).

    b. Investigate fabrication and joining processes for TPS, tankage, and structural materials.

    c. Evaluate high temperature and cryogenic insulation materials and other thermal control materials.

        (1) Investigate reusability of commercial high temperature insulations.

        (2) Investigate cryogenic foam insulations with 350 F usable temperature.

        (3) Evaluate candidate external insulation materials.

        (4) Investigate phase-change materials for temperature control.

    d. Evaluate coating materials and processes.

        (1) Oxidation protective coatings for refractory alloys and carbon materials.

        (2) Thermal control coating materials.

    e. Investigate materials for sealing, lubrication, and other nonstructural applications.

    f. Investigate problems of compatibility of specific materials with each other and with their environments and stress state.

WBS Number: 2.2.3
Orbiter Tasks (Cont)

(1) Examine compatibility of materials at high temperature.

(2) Examine compatibility of materials with fluids.

(3) Examine compatibility of materials with atmosphere.

g. Establish an approach for control of flammability, toxicity, and outgassing of materials.

h. Develop advanced composites for use in the Shuttle.

(1) Develop design concepts and data.

(2) Demonstrate by fabrication and test the weight savings inherent in this type of construction and identify cost data.

(3) Develop fabrication concepts and techniques.

(4) Tradeoff weight/cost data for advanced composites versus more conventional construction and materials.

i. Identify problem areas for maintainability from the standpoint of corrosion, compatibility, moisture absorption on insulation, etc. Provide information relative to the feasibility of maintenance techniques for coated materials such as refractory alloys, carbon composites, etc.

j. Establish a fracture control philosophy based on fracture mechanics, proof testing and NDT.

k. All of the above data will be summarized in the Materials section of the final Phase B Shuttle Report.

WBS Number: 3.2.3
Booster Tasks

Company:	Function:	Manager:
GD	Structures and TPS	F. Krohn

1. Design assistance and data compilation.

a. Review the preliminary design data book (prepared by NR) to verify booster needs. Provide supplemental data.

WBS Number: 3.2.3
Booster Tasks (Cont)

b. Assist design in material selection, fabrication, and inspection techniques.

c. The result of all investigations and associated experimental research studies will be included in the Materials section of the final Phase B report.

2. Experimental research programs. A test program will be defined (see Table 2-16 of Phase B proposals) that will determine materials properties for the booster tanks, structures, and thermal protection systems. A large portion of these tests will supply data at various temperatures, under various environments that can be used to generate preliminary design allowables. Tests to be performed include mechanical properties, physical properties, fracture toughness (plane stress, plane strain, and flaw growth), creep, life cycle, and fatigue.

*3. Provide support to design in order to perform trade studies in the following areas:

a. Nondestructive evaluation impact on the structural design (inspectability versus accessability).

b. Composite versus conventional structures.

*4. Conventional fabrication techniques (including welding, joining) will be examined in order to evaluate possible deficiencies in state-of-the-art.

*5. Support will be provided to structural design in order to establish a fracture control philosophy that will consider proof testing, static fracture toughness, flaw growth, stress corrosion cracking, and nondestructive evaluation. Data will be provided that reflects the expected environments and temperatures of the booster.

6. Investigate the potential problems of the booster vehicle with respect to compatibility, flammability, toxicity, and outgassing.

*Company-funded tasks.

SPACE SHUTTLE PHASE B
TASK DESCRIPTIONS

WBS TITLE: THERMAL PROTECTION SYSTEM

WBS Number: 2.2.4
Integration Tasks

Company:	Function:	Manager:
NR	Preliminary Design	W. A. Martin

1. Assure compatibility in analytic technique used in developing data for both orbiter and booster.

2. Achieve common use of test results to prevent duplication of effort.

Company:	Function:	Manager:
NR	Flight Technology	N. F. Witte

The analysis for determining the aerodynamic heating environment for the mated orbiter and booster will be conducted as indicated in the tasks listed below. The wind tunnel testing and associated activity are included in WBS 2.1.5.

3. Define atmospheric heating environment for the launch flight phase at sufficient body locations to support preliminary design activity.

4. Define atmospheric heating environment to support the following trade studies:

   a. Vehicle propellant distribution and main propulsion sizing.

   b. Vehicle alternate mission capability.

   c. Orbiter position on booster.

   d. Integral versus suspended main tanks.

   e. Straight versus delta wing orbiter for 200-nm cross range.

   f. Thermal structural concepts.

WBS Number: 2.2.4
Integration Tasks (Cont)

5. Document results identifying procedures and assumptions used in defining aeroheating environment.

   In addition, the analysis for determining the aerodynamic heating environment for the mated orbiter and booster requires the evaluation and documentation of the results of the following company-sponsored design study: Develop criteria and define sensitivity of aerodynamic heating to flow field assumptions (i.e., geometrical model, entropy layer swallowing), boundary layer transition, laminar and turbulent heating methods, and interference effects.

WBS Number: 2.2.4
Orbiter Tasks

Company:	Function:	Manager:
NR	Preliminary Design	W. A. Martin

1. Develop design data and prepare preliminary design sketches and layouts to define the thermal protection, thermal control, cryogenic tank insulation, and structure for the orbiter vehicles of the space shuttle system. Provide selection results of the thermal structural concepts trade study.

Company:	Function:	Manager:
NR	Vehicle Structures	R. A. Lusk

2. In support of the Preliminary Design group, the Vehicle Structures Engineering group shall identify design requirements and thermostress analytical data for the thermal protection system (TPS) design concepts. This effort is basically in support of the heat shield design and cryogenic tank installation design. The following data and effort will be developed and/or provided in support of the heat shield design:

   a. TPS concepts and structural recommendations based on stress analysis of candidate TPS designs, including the interaction with the primary orbiter structure.

   b. Results of buffet, flutter, and static aeroelastic analysis of candidate TPS designs.

   c. Recommended materials, and their characteristics and properties.

   d. Results of candidate materials tests.

   e. Support design evaluation tests.

WBS Number: 2.2.4
Orbiter Tasks (Cont)

f. Producibility information.

g. Thermally test a TPS panel.

For design of the cryogenic tank insulation, the following will be provided:

h. Thermo-stress analysis of cryogenic insulation.

i. Recommended materials and their characteristics, including related processes.

Company:	Function:	Manager:
NR	Flight Technology	N. F. Witte

3. The thermal design requirements and thermal response data (analysis) will be developed to support the TPS design definition as follows:

   a. Define TPS thermal design requirements (insulation, attachment isolation, coatings properties, etc.) and evaluate the TPS design adequacy: support the TPS concept trade study.

   b. Support propulsion system trade studies; size cryogenic insulation requirements for orbiter main tanks.

   c. Perform a space thermal control system (TCS) trade study utilizing active and passive TCS elements for satisfying the spaceflight subsystem thermal limitations; evaluate candidate TCS and recommend a TCS that is compatible with all mission phases.

4. In addition, this requires that NR evaluate and document the results of company-sponsored design studies, which include the tasks defined below:

   a. Develop parametric TPS thermal trade data on entry thermal requirements considering composite insulations, chemical phase change heat sinks, active cooling, structural temperature limits, external insulation, and hot structure TPS concepts.

   b. Develop transient temperature data for the primary structure to support the vehicle structures group stress analysis.

WBS Number: 2.2.4
Orbiter Tasks (Cont)

c. Define thermal requirements for development and qualification testing of the TPS.

d. Develop parametric data on cryogenic insulation requirements for the orbiter main propellant tanks considering ground purge, allowable boil-off rates, and local TPS insulation requirements.

e. Develop parametric data on thermal insulation and isolation of long-duration cryogenic propellant storage concepts for use in space.

f. Define thermal requirements for the propulsion systems development and qualification tests.

g. Develop parametric spaceflight temperature data for a typical orbiter vehicle thermal control system for a range of surface optical properties, insulation thicknesses, internal heat dissipation, and vehicle/earth/sun orientations.

h. Define with each responsible subsystem group the thermal limitations of each subsystem for each phase of the mission.

i. Determine the thermal environment and thermal design requirements for protecting vehicle subsystems during the prelaunch, launch, entry and post-entry mission phases.

j. Define the thermal requirements for the TCS and vehicle subsystems development and qualification tests for all orbiter mission phases.

5. The analysis for determining the aerodynamic heating environment for the orbiters will be conducted as indicated in the tasks listed below. The wind tunnel testing and associated activity are included in WBS 2.1.5.

a. Define atmospheric heating environment for launch, abort, and entry flight phases at sufficient body locations to support preliminary design activity.

b. Define atmospheric heating environment to support the following trade studies:

(1) Vehicle propellant distribution and main propulsion sizing.

(2) Vehicle alternate mission capability.

WBS Number: 2.2.4
Orbiter Tasks (Cont)

(3) Vehicle abort capability.

(4) Integral versus suspended main tanks.

(5) Straight versus delta wing orbiter for 200-nm cross range.

(6) Thermal structural concepts.

c. Document results identifying procedures and assumptions used in defining aeroheating environment.

6. In addition, the analysis for determining the aerodynamic heating environment requires the evaluation and documentation of the results of the following company sponsored design studies.

a. Develop criteria and define sensitivity of aerodynamic heating to flow field assumptions (i.e., geometrical model, entropy layer swallowing), boundary layer transition, laminar and turbulent heating methods, and interference effects.

b. Support determination of design entry flight profiles by providing parametric heating data considering pertinent range of velocity and altitude, angle of attack, vehicle configuration, laminar and turbulent flow.

c. Support definition of orbiter flight test requirements relative to simulation of aeroheating environment.

WBS Number: 3.2.4
Booster Tasks

Company:	Function:	Manager:
GD	Structure and TPS	F. Krohn

1. Define the thermal protection system design criteria. Periodically review and update as required.

2. Support vehicle configuration trade studies listed in WBS 3.2.1 by providing a definition of the thermal protection systems applicable to a straight-wing, a delta-wing, and a stowed-wing configuration. Assist in TPS sizing to determine TPS weights coefficients for input to the vehicle synthesis program. Provide an assessment of TPS characteristics to facilitate vehicle configuration selection.

WBS Number: 3.2.4
Booster Tasks (Cont)

3. Support the orbiter-on-booster-position trade study to determine the impact on TPS requirements due to variation in the booster orbiter interactions and orbiter plume impingement with different orbiter positions.

4. Perform thermostructural tradeoff studies.

   a. Body heat shield arrangements.

   b. Hot versus thermally protected wing.

   c. Hot versus thermally protected stabilizers.

   d. Coated refractory versus RPP for leading edges.

   e. Outer shell stiffening concepts for acoustical fatigue resistance.

   Assess the tradeoff candidates on the basis of low weight, low cost, reliability, technological status, and amenability to inspection and repair.

5. Establish purging, pressurization, and venting requirements and define the associated TPS criteria.

6. Investigate the relationships between the TPS and the cryogenic insulation system.

7. Prepare detail layouts of each significantly different area of the thermal protection system.

8. Define fabrication techniques and assembly methods for each area of the thermal protection system.

9. Perform design investigations of the TPS structural configurations with consideration of fabrication and assembly methods to determine nonoptimum factors for inclusion in structural weight estimates.

10. Determine access requirements and make provision by local access panels or disassembly capability in the heat shield shell.

11. Define thermal control systems for critical areas, subsystem compartments, and personnel compartments.

WBS Number: 3.2.4
Booster Tasks (Cont)

12. Perform structural analysis of thermal protection systems per WBS 3.2.2 in support of trade studies and preliminary design. Analysis will include considerations of discrete panel pressures, thermal stress, creep, fatigue and sonic fatigue resistance.

*13. Design TPS test specimens and conduct tests for substantiation of structural and thermal analysis and to assist verification of structural weight estimates.

14. Provide preliminary design drawings of each major TPS component.

Company:	Function:	Manager:
GD	Flight Technology	S. V. Starr

15. The aerothermodynamic environment for the booster will be determined by dividing the vehicle into simple geometric shapes such as a flat plate, sphere, cone, or cylinder. Aerodynamic heating will then be predicted for these simple shapes. The selection and identification of these vehicle regions and a discussion of analytical and empirical relationships used during the study will be documented. Several regions on the booster are not amenable to theoretical analysis and require identification. These regions will be identified and emphasized during wind tunnel tests and data analysis.

16. A theoretical and literature survey of all available data will be conducted and reported for in-depth thermal analysis. These studies will investigate but not be limited to the following:

    a. Trajectory and atmospheric dispersions.

    b. Scalability of wind tunnel tests.

    c. Boundary layer transition criteria.

    d. Comparison of heat transfer rate techniques and recommended applicability.

17. Correlate the results of the Phase B wind tunnel tests with analytical techniques.

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*Company-funded Tasks

WBS Number: 3.2.4
Booster Tasks (Cont)

18. Define atmospheric heating environment and structural response at sufficient body locations to support design activity.

19. Provide analysis of thermal control systems in subsystem and personnel compartments.

20. Define atmospheric heating to support the following studies:

    a. Vehicle configuration trades.

    b. Vehicle propellant heating and main propulsion sizing.

    c. Orbiter/booster relative positioning.

    d. Thermal structural concepts.

    e. Material selection for TPS system.

21. Define orbiter plume impingement heating on booster upper surfaces during separation.

22. Define booster base heating during launch phase of flight.

23. Determine heating environment from the attitude control rockets.

24. Correlate thermal protection system test results with analytical results.

SPACE SHUTTLE PHASE B
TASK DESCRIPTIONS

WBS TITLE: MASS PROPERTIES

WBS Number: 2.2.5
Integration Tasks

Company:	Function:	Manager
NR	Preliminary Design	W. A. Martin

1. Generate mass property data for the space shuttle system in accordance with Specification MIL-M-38310A, as modified by NASA. The contents shall be modified to provide design data statement, detail weight statement, sequence mass properties statement, and summary mass properties statement for the integrated vehicles, monthly status reports.

2. Prepare a detail mass properties data report for integrated vehicles in accordance with Specification MIL-M-38310A, as modified by NASA and submitted at the eigth and twelfth month of the contract.

3. Develop center-of-gravity and moments-of-inertia data for integrated vehicle for all conditions from liftoff to landing:

   a. Locate center of gravity of orbiter and booster combination for significant operational sequences.

   b. Calculate I_{ox}, I_{oy}, and I_{oz} data for significant operational sequences.

4. Maintain liaison with GD mass properties personnel to assure a consistent approach in calculating and reporting mass properties.

5. Evaluate and document the results of the company sponsored design study, which includes the following tasks:

   a. Define the automated technique for rapid generation and dissimination of mass property data for vehicle designs.

   b. Determine criteria and requirements for conducting a weight risk analysis for determining potential payload sensitivity to alternative flight vehicle design concepts for space transportation.

   c. Define the criteria and requirements for a plan to be implemented during Phase C to accomplish mass properties management. The plan shall include definition of objectives and budgets, contingencies, mode of operation control mechanisms to be used, and corrective action to be taken if detrimental deviations occur.

WBS Number: 2.2.5
Orbiter Tasks

Company:	Function:	Manager:
NR	Preliminary Design	W. A. Martin

1. Generate mass property data for the orbiter in accordance with Specification MIL-M38310A, as modified by NASA. The contents shall be modified to provide design data statement, detail weight statement, sequence mass properties statement, and summary mass properties statement for both orbiters' monthly status reports.

2. Prepare a detail mass properties data report for both orbiters in accordance with MIL-M-38310A, as modified by NASA and submitted at the eigth and twelfth month of the contract.

3. Develop center-of-gravity and moments-of-inertia data for both baseline orbiters for all conditions from liftoff to landing:

   a. Locate center of gravity of all components.

   b. Calculate I_{ox}, I_{oy}, and I_{oz} data for all components down to the detail weight level.

4. Develop mass properties data for tradeoff and sensitivity studies, and assist in vehicle sizing:

   a. Maintain weight equations and provide coefficient inputs for space-shuttle-synthesis computer program.

   b. Calculate weight effects of tradeoff variations and incorporate into synthesis program inputs.

   c. Calculate structural increments for all major design features.

WBS Number: 3.2.5
Booster Tasks

Company:	Functions:	Manager:
GD	Mass Properties	R. L. Benson

1. Prepare a summary weights report for the booster in accordance with Specification MIL-M-38310A. The content shall be modified to provide design data statement, detail weight statement, sequence mass properties statement, and summary mass properties statement monthly report.

WBS Number: 3.2.5
Booster Tasks (Cont)

2. Prepare a detail mass properties data report for the booster in accordance with Specification MIL-M-38310A, as modified by NASA and submitted at eight and twelfth month of the contrast.

3. Maintain liaison with NR mass properties personnel to assure a consistent approach in calculating and reporting mass properties and to assist in mass properties calculations for the integrated vehicle.

SPACE SHUTTLE PHASE B
TASK DESCRIPTIONS

WBS TITLE: STRUCTURAL TEST PROGRAM

WBS Number: 2.2.6
Integration Tasks

Company:	Function:	Manager:
NR	Vehicle Structures	R. A. Lusk

1. Integrate the orbiter test plan requirements with the booster test plan requirements proposed by General Dynamics.

2. Develop a structural, dynamic, and thermo test program to (1) verify weight prediction, (2) demonstrate reusability, (3) demonstrate producibility, (4) verify thermal response predictions, (5) verify proposed concepts feasibility, (6) provide design data, (7) verify structural analysis, (8) demonstrate structural adequacy, (9) demonstrate cryogenci insulation, (10) develop repair techniques, and (11) identify design, fabrication, and maintenance "surprises" early.

WBS Number: 2.2.6
Orbiter Tasks

Company:	Function:	Manager:
NR	Vehicle Structures	R. A. Lusk

1. Identify the major vehicle components to be tested and prepare a proposal for a program to fabricate and test the critical component assemblies.

   a. Major components to consider are the fuselage/wing carry-through structure and empennage for the straight wing orbiter and the LH_2 region for the delta wing orbiter.

   b. Typical items of interest are the heat shield, wing carry-through structure, cargo compartment, booster attachment, landing gear attachment, empennage attachment, cryogenic tank/structure, double lobe tank, and doors.

   c. Structural components will be subjected to aerodynamic and inertia loads, entry thermal profile cycles, landing loads, engine thrust loads, and cyclic actuator loading.

WBS Number: 2.2.6
Orbiter Tasks (Cont)

2. Develop element test requirements to verify technical assumptions, analysis methods, and material performance.

    a. Compression panels, shear panels, and crippling specimens will be tested.

    b. Full-scale TPS panels will be tested with flight pressure and temperature profiles.

3. Document the test results in the form of engineering analysis reports to substantiate analytical assumptions used to obtain weights and internal load and thermal distributions.

WBS Number: 3.2.6
Booster Tasks

Company:	Functions:	Manager:
GO	Vehicle Structures	Lightbown

This task will involve the preparation of a proposal for a program to fabricate and test major structural assemblies. The objective of the program will be to demonstrate producibility, to provide data for design purposes, and to substantiate structures and TPS weight predictions. The design and analysis accomplished on the baseline structural arrangement under Elements 2210, 2220, and 2230 will be used for an initial definition of the specimen for proposal purposes. Test requirements will be established; test facilities will be selected; and program cost estimates will be obtained.

1. Define test specimen using the results of the baseline structure/TPS study.

2. Investigate thermal and structural modeling scale effects, and establish specimen scale.

3. Review available test facilities.

4. Conceptually design the test specimen using design, analytical, and fabrication techniques consistent with the full-scale design.

5. Establish test requirements.

6. Establish instrumentation requirements.

WBS Number: 3.2.6
Booster Tasks (Cont)

7. Compute program costs.

8. Prepare proposal.

9. Define revisions to specimen, if any, resulting from tradeoff and subsequent design studies.

SPACE SHUTTLE PHASE B
TASK DESCRIPTIONS

WBS TITLE: PROPULSION SYSTEM/VEHICLE INTEGRATION

WBS Number: 2.3.1.1
Integration Tasks

Company:	Function:	Manager:
NR	Fluids and Propulsion	R. E. Field

1. System Commonality. Perform analyses using a common main engine powerhead for both the booster and orbiter vehicles; identify orbiter main engine requirements and determine a composite set of interface requirements for an engine common to both vehicles.

2. Requirements and Sensitivities. Prepare parametric and trade study data, and conduct studies as delineated in the following subparagraphs for obtaining the desired orbiter main engine characteristics and interface requirements and sensitivities. The variations and alternatives for each subparagraph item will cover the range of values specified in the main engine SOW (refer to paragraph 4.1.4.1 of DCN 1-0-21-00001). Main engine parametric performance data will be obtained from the baseline NASA preliminary Space Shuttle Vehicle/Engine ICD.

   a. Normal Power Level (NPL), Emergency Power Level (EPL), Nozzle Expansion Ratio, and Nominal Mixture Ratio. Define the payload capability, number of booster and orbiter engines, configuration impact and complexity, engine development time, fail-operational/fail-safe capability as a function of NPL and EPL, and nonrecurring and recurring costs. Employ vehicle synthesis program. Major considerations are engine commonality between stages, configuration and performance impact of base area, vehicle size and mass fraction, engine specific impulse, weight impact of T/W, q max and resulting loads, provisions for engine-out. Recommend NPL, EPL, nominal mixture ratio, and nozzle expansion for the orbiter.

   b. Orbiter Engine Nozzle. Evaluate the requirements for two-position nozzle. Major considerations are g limits, air loads, thermal control, actuation times, effect on power generation system, low-altitude abort thrust requirements, and engine installation length effects. Recommend nozzle area break point for two-position nozzle or a fixed nozzle, as required.

WBS Number: 2.3.1.1
Integration Tasks (Cont)

c. Throttle Requirement, Minimum Power Level (MPL). Define MPL for 3-g limit, for orbit maneuvers (Task 4.3.1.3), and abort cruise (if required). Define nonrecurring and recurring cost, engine development time and risk, and engine complexity for percent NPL identified for each function (Tasks 4.1, 4.3.1.1, and 4.3.1.3). Recommend MPL for the orbiter.

d. Gimbal Angle and Rate. Define orbiter gimbal angle versus ascent time. Consider drift, wind shear and gusts (for low-altitude abort modes), separation dynamics, and engine-out conditions, Define effect of gimbal rate and acceleration, alternative control concepts, and feedback. Consider center-of-gravity tracking requirement, differential gimbaling for roll control, and impacts of separate stage flight testing. Define cost and schedule impact of requirements on engine (Tasks 4.1, 4.3.1.1 and 4.3.2). Recommend gimbal angle, rate, and acceleration for the orbiter.

e. Gimbal System Type and Location (CS-2.3.1.6-53011). Define engine actuation system (EAS) designs for individual engine systems versus central vehicle system, weight, complexity, nonrecurring and recurring cost, maintainability, fail-operational, and fail safe (Tasks 4.3.1.1 and 4.3.6 and refer to WBS 2.3.6). Determine number of engines required to gimbal for vehicle control and also determine their location. Recommend gimbal system type and location for the orbiter.

f. Engine Controller Functional Requirements and Location. Define desired functional requirements and location considering vehicle integrated avionics concepts. Consider engine control, engine status, and performance monitoring/diagnostics, malfunction detection. Define nonrecurring and recurring cost, complexity, maintenance, and development time (Tasks 4.3.1.1 and 4.3.2). Recommend controller functional requirements and location.

g. Engine Plume Effects. Define orbiter main engine exhaust plume characteristics for GD evaluation (refer to WBS 3.3.9) of effects on booster due to starting orbiter before separation, and the main engine effects on the OMS engine, and also effects on orbiter engine for various modes, including abort conditions. Recommend orbiter engine operating modes and determine performance effects.

WBS Number: 2.3.1.1
Integration Tasks (Cont)

h. Propellant Tank Pressurization Requirement. Define system concept, pressurant type, effect of pressurant temperature, pressure, and flow rate required versus time. Consider NPL, EPL, and MPL operation (Task 4.3.1.1). Recommend pressurant design flow rate, temperature, and pressure.

i. Propellant Utilization (PU) System (CS-1.3.1.1-21005). Define propellant residual and vehicle payload versus active PU or no PU, engine MR range, loading tolerance, PU accuracy for booster and orbiter. Consider EPL operation. Define nonrecurring and recurring cost, engine development time, complexity, and maintenance (Task 4.3.1.1). Recommend engine MR range and engine control accuracy.

j. Engine/Vehicle Dynamic Coupling (Pogo). Determine if pogo suppression should be active or passive type. Determine if pogo suppression system should be supplied as part of vehicle, engine, or combination. Recommend pogo suppression method.

k. Transient System Operation. Identify possible vehicle fluid dynamic or structural constraints which should be imposed on the main engine. Define start/shutdown contraints.

3. Evaluation and Recommendations. Evaluate the orbiter main engine design and performance requirements and sensitivities from the above task using the results of the engine manufacturer's analysis data (in accorandance with paragraph 4.1.4.1 of the Main Engine S.O.W.) for sensitivities related to cost, schedule, development, and the like. Based on this evaluation, provide NASA with recommendations defining the engine characteristics for each subparagraph item listed in the previous task. Results are to be reported in Propulsion system trade study report in accordance with Appendix F, NASA SOW RFP 10-8423.

4. Interface Coordination. Provide continual coordination of the main engine interface for the balance of the vehicle study. Following issuance of the updated NASA Space Shuttle Engine/Vehicle ICD, coordinate the vehicle design study with NASA, MDC, and the engine manufacturers for additional detailed interface definitions, and update them based on the preliminary vehicle design definition. These definitions will include performance and design requirements, measurement requirements for monitoring and checkout, control system design, installation, connections, hazards analysis, development, and test requirements for the main

WBS Number: 2.3.1.1
Integration Tasks (Cont)

engine. Results are to be reported in the following documents:

a. Propulsion system report (interim and final)

b. NASA briefings

c. Final report

Company:	Function:	Manager:
NR	Integrated Electronics	G. C. Anderson

Support Propulsion and Fluids in Engine and Vehicle Integration Studies.

5. Provide the vehicle flight control system requirements necessary for evaluating effects of engine gimbal angle and rate, and gimbal type and location.

6. Define the effects on avionics and flight control systems of variations in engine characteristics as applicable to design thrust size for ascent phase and orbit maneuvering phase, throttled thrust levels and variation, engine-out considerations, gimbal angle and rate, gimbal type and location, propellant utilization systems requirements, and engine controller requirements and locations.

Company:	Function:	Manager:
NR	Integrated Electronics	G. C. Anderson

Results are to be reported in the following documents:

a. Propulsion system report in accordance with Appendix F, NASA SOW RFP 10-8423

b. NASA briefings

c. Final report

WBS Number: 3.3.1.1
Booster Tasks

Company:	Function:	Manager:
GD	Propulsion	A. Schuler

1. Perform trade study to determine optimum main engine thrust levels (NPL and EPL). Study parameters will include sea level thrust variations from 250K to 600K, area ratios from 35:1 to 75:1, and EPL up to

WBS Number: 3.3.1.1
Booster Tasks (Cont)

125 percent of NPL. The number of engines required will be determined in conjunction with the parametric study. Recommended booster engine NPL, EPL, area ratio, engine size, and number of engines will be provided.

2. Perform analysis to define nominal booster engine mixture ratio within the ranges of 5:1 to 7:1. Major considerations are engine specific impulse effects and vehicle sizing.

3. Define the minimum power level (MPL) required for the booster to meet the maximum acceleration constraints for the combined launch vehicle.

4. Perform analysis to identify this gimbal angle and the rate requirements for the booster. Analysis with encompass angles up to 10 degrees, angular rates from 5 to 15 deg/sec, and angular accelerations to 30 radians/sec^2. Considerations will include center-of-gravity tracking, windloads, engine-out, abort requirements and differential gimbaling for roll control. The recommended gimbal angles, gimbal rates, and accelerations for the booster will be established.

5. Perform analysis to define the propellant tank pressurization requirements and system design. Analyze use of gaseous propellants and helium and the effects on vehicle design and performance. Define booster pressurization requirements, and provide recommended pressurant and system design, and operating parameters.

6. Perform a trade analysis to determine if a propellant utilization system is required for the booster (CS-1.3.1.1-21005). Determine operational mixture ratio setting and dispersions and propellant tanking accuracy requirements without PU. Define mixture ratio control range and accuracy with a PU system; establish vehicle performance/cost effectiveness; and provide recommendations concerning incorporation of a PU system in the booster vehicle design.

7. Evaluate engine controller functional requirements to determine if engine-dedicated controllers, vehicle-integrated controller, or some combination of both methods should be used. Engine control and checkout will be considered along with integrated avionics concepts to establish recommended controller functional requirements and location.

WBS Number: 3.3.1.1
Booster Tasks (Cont)

*8. Perform engine/vehicle feed system analysis to identify possible fluid dynamic and structural constraints which affect engine design requirements. Consider both manifold and individual feed lines. Perform trade analysis of active versus passive pogo suppression systems and make recommendations with respect to approach and whether or not to include as part of the engine design or include in the vehicle supplied lines.

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* Task to analyze orbiter engines plume effect on the booster is included in WBS 3.3.9, Separation System, and Gimbal System Type and Location appears in WBS 3.3.5.

SPACE SHUTTLE PHASE B
TASK DESCRIPTIONS

WBS TITLE: MAIN PROPULSION SYSTEM

WBS Number: 2.3.1.2
Integration Task

Company:	Function:	Manager:
NR	Fluids and Propulsion	R. E. Field

1. Review booster/orbiter main propulsion subsystem designs as they evolve to define potential areas of commonality. Identify such areas to the subassembly and component level.

2. Determine candidate component design requirements and characteristics that provide stage subsystem commonality. Define vehicle performance, cost, and operations impact.

3. Select and recommend common components and operational criteria.

4. Provide support to NASA technology contracts. Attend integration meetings and provide interface data. Maximize use of technology contract data in Phase B vehicle studies.

5. Define possible techniques of assessing propulsion and mechanical systems integrity by use of integral leak-detection systems, sensing parts, instrumentation, component position indications, etc. Define mechanical and propulsion systems checkout interfaces with ground and/or on-board checkout systems.

WBS Number: 2.3.1.2
Orbiter Tasks

Company	Function:	Manager:
NR	Fluids and Propulsion	R. E. Field

1. Engine Design Characteristics Optimization. Conduct studies of main engine design options to define optimum thrust, mixture ratio, nozzle area ratio, gimbal angle and rate, gimbal system type and location, interface requirements, thermal protection, and control and recorder location. This optimization shall be conducted in support of the following major trade studies:

   Vehicle Propellant Distribution and Main Propulsion Sizing (CS-1.1.2-13002) and Gimbal System Type and Location (CS-2.3.1.6-53011).

WBS Number: 2.3.1.2
Orbiter Tasks (Cont)

Results are to be reported in the following documents:

a. Propulsion system tradeoff report (interim and final)

b. NASA briefings

c. Final report in accordance with Appendix F, NASA SOW RFP 10-8423

2. Propellant Utilization System Requirements (Trade Study CS-1.3.1.1-21005). Evaluate the impact of propulsion system, subsystem, and component tolerances on vehicle performance capability in order to determine the need for a PU System. Consider engine (F, I_{sp}, MR, and EPL), tankage (loading, gauging, and fuel bias), pressurization (ullage, pressure, temperature) subsystems and determine systematic and random errors. Define payload capability with and without PU system and recommend approach.

   Results are to be reported in the following documents:

   a. Propulsion system tradeoff report (interim and final)

   b. NASA briefings

   c. Final report in accordance with Appendix F, NASA SOW RFP 10-8423.

3. Conduct company-sponsored analytical study to define the sensitivity of propulsion system mission performance to subsystem and component variabilities. Develop analytical tools as required. Include the effects of engines, feed system, pressurization, tankage, gauging, and GSE.

4. Feed Subsystem Concept Selection. Define feed system concept. Consider line configuration, manifolding, propellant fill, component redundancy, thermal protection (including maintenance and reliability), propellant jettison, and preconditioning. Evaluate the requirement for PVC's, considering both engine-mounted and stage-mounted boost pumps. Conduct analyses and design studies required to determine number and location of components, line size, routing, preconditioning requirements, and weights. Also, consider main system/OMS interconnects. Evaluate feed subsystem dynamics. Evaluate and recommend concept on the basis of safety, vehicle integration, weight, residuals, complexity, and abort requirements.

5. Develop, in company-sponsored activity, the methodology and analytical tools required to define propellant temperature and quality distribution in cryogenic feed systems as a function of time. Major emphasis is to be placed on pre-fire and engine start-up transient phases.

WBS Number: 2.3.1.2
Orbiter Tasks (Cont)

6. Tankage Analysis and Requirements. Determine the impact of tank number, location, and configuration on propulsion system performance and operational characteristics. Define residuals, volumes, internal hardware, insulation requirements, and propellant usage schedules. Determine pressure schedules, purge, and fill and drain requirements. Recommend concept.

7. Pressurization Concept Selection. Evaluate the relative merits of candidate pressurization subsystem concepts: Include bootsrap and GH_e pre-pressurization. Define tap-off flow and pressure control schedules. Determine required component redundancy. Evaluate effect of NPSP on tankage and pressurization system weight versus increased engine boost pump requirements. Assess impact of abort criteria and stratification effects. Recommend concept.

8. Develop, in company-sponsored activity, an automated analytical technique to define cryogenic propulsion system feed tank and tank pressure variations during engine support.

9. Duty Cycle Definition. Based on mission requirements and alternate concept characteristics, define mission time-line oriented duty cycle and system environment. Include firing duration, pre- and post-firing operations, and power requirements.

10. Determine, in company-sponsored activity, the characteristics of large cryogenic propulsion system components (i.e., valves, regulators, etc.) and define life, failure rate trends, and the impact on system failure probability.

11. Define, in company-sponsored activity, the leakage characteristics (internal and external) of cryogenic components employed in pressurization, tankage, and feed subsystems. Determine required leakage limits, and sensing and purge techniques.

12. FMEA. Prepare FMEA's as required to support system, subsystem, and component selection.

    Items 3, 4, 6, and 9 shall be documented and submitted for NASA review and approval as per:

    a. Mid-term briefing

    b. Final report

WBS Number: 2.3.1.2
Orbiter Tasks (Cont)

13. Preliminary Design Definition. Define NASA-approved concept preliminary design, including weight, performance, installation, and duty cycle. Evaluate and recommend component concepts. Define interfaces, servicing, hazards, and maintenance characteristics. Define system development schedule, cost, and technology requirements.

    Report results as per:

    a. NASA briefings

    b. Final report

    c. Orbiter CEI specification.

WBS Number: 3.3.1.2
Booster Tasks

Company	Function:	Manager:
GD	Propulsion	A. Schuler

Participate in a trade study of the booster main propulsion system, including characteristics and performance of the main propulsive engine; propellant tanks and feed system; and pressurization. The effort shall include engine-out capability and power levels, thermal environment, propellant loading, feed and utilization, and pneumatic system. The considerations of thrust-level optimization, expansion-ratio optimization, emergency power-level optimization, energy power-level optimization, throttle requirements, gimbal angle, engine-controller functional requirements, and engine duty cycle will be included. The major trade-off tasks for Vehicle Propellant Distribution and Main Propulsion Sizing is accomplished in Task 3.3.1.1. The additional main propulsion tasks are as follows:

1. Perform company-sponsored analysis to define the PU system requirements (for PU or no PU case, refer to 3.3.1.1, PU task). Determine the gauging system tolerances and MR control range usage. Define the systematic and random errors and determine the fuel bias requirements, as well as engine dispersion requirements.

2. Perform company-sponsored analysis of the propellant loading requirements to define loading sequence and rate requirements as well as drain and tank purge requirements. Analyze and recommend interface between vehicle and ground equipment, considering countdown time, holds, abort, and turn-around time requirements.

WBS Number: 3.3.1.2
Booster Tasks (Cont)

3. Accomplish company-sponsored tradeoff analysis to determine the propellant feed subsystem. Study of routing, insulation (considering maintenance and reliability), propellant dumping, preconditioning and component redundancy will be accomplished. Tradeoffs will consider line performance (pressure loss), sizes, and weights and will also consider system dynamics, residuals, complexity, and reliability.

4. Accomplish company-sponsored tankage analysis to determine configuration, including relative positioning, internal hardware, volumes, bulkheads, and thermal protection requirements. The propellant quantity guaging requirements for loading, in-flight operation, and depletion will be defined, and configuration recommendations will be provides.

5. Perform company-sponsored trade analysis to define the pressurization subsystem. Analyze the pressure schedule and control requirements, the pressurant characteristics (pressure, temperature, and type), and sources, and the vent requirements in order to establish the system configuration. Criteria for analysis are to include performance, cost, weight, and relative complexities. Stratification effects are to be considered in defining pressure schedules.

6. Accomplish failure modes and effects analysis (FMEA) on the main propulsion system as required to assist in system, subsystem and component concept and configuration definition.

7. Conduct company-sponsored analysis to define the duty cycle of the main propulsion system, including operating duration, environment, pre- and post-firing operations and power requirements.

8. Accomplish preliminary design and system definition for the booster main propulsion system. Definition of system design, installation and interfaces will be provided. Potential development problems will be ascertained, and maintenance and operational requirements will be defined.

9. Determine weight, installed center of gravity, installed moment of inertia, material designation, and SP6004 code. Prepare input for digital computer; review design for optimum weight; and establish target weights for weight control.

SPACE SHUTTLE PHASE B
TASK DESCRIPTIONS

WBS TITLE: ORBIT MANEUVERING SYSTEM

WBS Number: 2.3.1.3
Orbiter Tasks

Company:	Function:	Manger:
NR	Fluids and Propulsion	R. E. Field

1. Review booster/orbiter main propulsion systems and ACPS to determine if potentially common component requirements exist and identify such areas.

2. If such areas exist, determine candidate component designs and evaluate their resulting impact on system characteristics.

3. Recommend common components.

4. Provide support to NASA technology contracts. Attend integration meetings, and provide interface data. Maximize use of technology contract data in Phase B vehicle studies.

5. Define possible techniques of assessing propulsion and mechanical systems integrity by use of integral leak-detection systems, sensing parts, instrumentation, component positions indications, etc. Define mechanical and propulsion systems checkout interfaces with ground and/or onboard checkout systems.

6. Orbit Maneuvering Propulsion System Concepts and Utilization. Conduct a tradeoff study of candidate OMS concepts and their respective applicability to all orbiter flight regimes, including aborts. Consider main, auxiliary, and ACPS engines; separate versus integrated tankage and systems; duty cycle; alternate missions; chill mode; tank location; thrust level; and TVC. Define system weight, performance, interface, safety, and cost for system alternatives, considering alternate mission requirements. Determine number of starts, propellant consumption (impulse, engine and line chill, line residual losses, boiloff, etc.), division of orbital functions, and relative technical risk. This task is defined as Trade Study CS-1.3.1.3-21010. This trade study will consider the following:

WBS Number 2.3.1.3
Orbiter Tasks (Cont)

a. Engines
   - Throttled main engine
   - RL10A3
   - Modified RL10
   - Optimum pump fed orbital maneuvering engine, both gas generator cycle and expander cycle
   - High-pressure RCS engine
   - Low-pressure RCS engine

b. Impact of one engine ready versus two engines ready to fire for orbital maneuvers.

c. Isolation valve location (at tank or engine) will not be considered in initial trade studies but will be considered in design studies of selected OMS concept.

d. Engine envelope versus thrust level, expansion ratio, and performance trades will consider vehicle envelope constraints and potential to increase RL10 expansion ratio.

e. Ability of current RL10A-3 to meet shuttle life and maintenance goals will be evaluated. Required modifications and costs will be identified.

f. Assess potential impact of a propellant settling requirement versus no propellant settling requirement on OMS configuration tradeoff study results.

g. Engine NPSH requirements versus vehicle tankage and pressurization considerations.

Recommend system concept and report results in the following documents:

a. Propulsion system tradeoff report (interim and final)

b. NASA briefings

c. Final report in accordance with Appendix F, NASA SOW RFP 10-8423.

WBS Number: 2.3.1.3
Orbiter Tasks (Cont)

7. Requirements and Duty Cycle Definition. Determine the OMS design requirements based on mission requirements and design concept alternatives. Define duty cycle, including propellant firing duration, pre- and post-firing operations (i.e., chilldown, purge, etc.), and power requirements for baseline and alternative missions.

8. Feed Subsystem Selection. Select and recommend OMS feed system design approach. Consider series versus parallel feed, interconnects, servicing, chill, component redundancy, insulation, routing, and propellant jettison. Define optimum feed system concept, including number and location of components, line size, routing, preconditioning features and requirements, pressure losses, and weight. Recommend feed subsystem concept.

9. Develop, in company-sponsored activity, the methodology and analytical techniques required to define propellant temperature, quality, and quantity distribution within isolated feedlines during boost and orbital coast mission phases. Conduct analyses of various design alternatives and mission timelines to define chilldown and residual losses.

10. Determine, in company-sponsored activity, the characteristics of orbit maneuvering propulsion system components (i.e., valves, regulators, etc.) and define life, failure rate trends, and the impact on system failure probability.

11. Tankage Analysis and Requirements Definition. Conduct engineering studies to define optimum tankage configuration and requirements. Consider various OMS propellant source options, number and location of tanks, feed concept, tank pressure schedule, propellant location control, gauging, and thermal management concept. Determine tankage requirements, including pressure, volumes, and propellant usage schedule. Evaluate candidate ullage positioning and gauging concepts on the basis of overall system weight, impact on system operational capability and technical risk. Determine PU system requirements. Recommend tankage concept.

WBS Number: 2.3.1.3
Orbiter Tasks (Cont)

12. Develop, in company-sponsored activity, the methodology and analytical techniques required to define time variant pressurization system operating characteristics over a complete mission time line. This shall include ullage mass, pressure and temperature, and propellant temperature and mass, all as functions of mission time. Employ this technique to analyze various space propulsion system configurations, design alternatives, and mission variations.

13. Pressurization Subsystem Concept Selection. Determine the optimum OMS pressurization subsystem concept and its attendant characteristics. Consider GH_e (ambient or cryogenic), and GO_2/GH_2 pressurants, pressurant source (engine bleed, ACPS, and stored), pressure control, component redundancy, venting mode, and thermal management subsystem integration. Define system weight, performance, interface, safety, and relative cost for alternative pressurization system concepts. Consider alternative missions and various operating and quiescent modes. Define pressure and vent schedule. Recommend optimum concept.

14. FMEA. Conduct, as required, FMEA's to assist in system, subsystem, and component selection. Items 7, 8, 11, 13, and 14 shall be documented and submitted for NASA review and approval in the following documents:

    a. Mid-term briefing

    b. Final report

15. Preliminary Design Definition. Define selected concept preliminary design including weight, performance, installation, and duty cycle. Evaluate and select component concepts. Define interface, servicing, hazards, safety, and maintenance characteristics. Define system development schedule, cost, and technology requirements.

    Report results as per:

    a. NASA briefings

    b. Final report

    c. Orbiter CEI specification.

SPACE SHUTTLE PHASE B
TASK DESCRIPTIONS

WBS TITLE: ATTITUDE CONTROL SYSTEM

WBS Number: 2.3.1.4
Integration Tasks

Company:	Function:	Manager:
NR	Fluids and Propulsion	R. E. Field

1. Provide coordination between NASA, NR, and GDC to ensure study commonality between orbiter/booster ACPS elements and their design philosophy wherever practicable. This effort will consider commonality in the sense of system and component technology, material solution, testing requirements, and hardware development with cost, performance, and minimal system development risk as criteria.

2. Prepare and develop overall ACPS study plans defining in detail tasks, input data, system requirements, and expected data output.

3. Provide support to NASA technology contracts. Attend integration meetings and provide interface data. Maximize use of technology contract data in Phase B vehicle studies.

4. Define possible techniques of assessing propulsion and mechanical systems integrity by use of integral leak detection systems, sensing parts, instrumentation, component position indications, etc. Define mechanical and propulsion systems checkout interfaces with ground and/or onboard checkout systems.

WBS Number: 2.3.1.4
Orbiter Tasks

Company:	Function:	Manager:
NR	Fluids and Propulsion	R. E. Field

1. Prepare, coordinate, and update orbiter ACPS study plans defining in detail tasks, input data, system requirements, and expected output data. Review and integrate applicable company-sponsored technical study data and methodology into applicable portions of the orbiter ACPS study on a timely basis.

WBS Number: 2.3.1.4
Orbiter Tasks (Cont)

2. Define subsystem requirements and ACPS functions in terms of vehicle/mission constraints. Consideration will be given to the following:

   a. Attitude Control Maneuvers. Translation and rotation.

   b. Physical Features. Geometry, thruster location, and number of thrusters.

   c. System Performance. Minimum impulse bit capability, maximum duration burn, and specific impulse.

3. Collect and evaluate vendor data for ACPS component performance, physical and design characteristics, cost, and availability. Included will be the available data for thrusters, propellant storage, feed and pumping systems, accumulators, and components, such as valves, heat exchangers, gas generators, system controls, and instrumentation.

4. Where current vendor data are not available for the components mentioned in Task 5, the required data will be developed in company-sponsored activity by use of available engineering techniques and existing data to provide the best possible estimates.

5. In company-sponsored activity, identify and evaluate system concepts for application to the orbiter ACPS.

   a. Conceptual System Definition

      (1) Identify thruster location and thrust levels to provide required linear and angular accelerations for NASA-established minimum, nominal minimum, nominal maximum, and maximum reaction rates (consider, but do not limit to, thruster placement which will allow a single engine for all axes and which is common for booster and orbiter).

      (2) Determine propellant usage rate and quantity for thruster locations and reaction rates for vehicle and systems developed in accordance with item (1).

WBS Number: 2.3.1.4
Orbiter Tasks (Cont)

b. System Studies

(1) Identify propellant sources, and design and operational constraints.

(2) Synthesize candidate propellant conditioning systems while meeting fail-operational/fail-safe criteria, and identify associated volumetric and weight penalties.

(3) Refine system analytical models for system sensitivity studies.

c. System Sensitivies. Determine system balances and optimize components through tradeoffs, concurrently affecting all ACPS components while satisfying vehicle/mission constraints.

(1) Determine ACPS weight sensitivity to engine chamber pressure and engine O/F ratio for both low and high chamber pressure systems.

(2) For systems which require gas generators, determine O/F ratios over the allowable exit temperature range.

(3) When considering sensitivity of system weight to overall O/F ratio, determine the O/F ratio of available residuals for those systems concepts that can utilize available residuals. It is necessary to know the probable residual (or boiloff) O/F ratio before the system weight of those concepts can be optimized with respect to O/F ratio.

(4) For all systems, determine the engine thrust level variation with changes in propellant inlet temperature and pressure and reduce it to tolerable level.

(5) For low-pressure systems determine the system weight sensitivity to distribution lines and component pressure drop.

(6) In systems requiring pumps, compressors, turbines, heat exchangers, etc., determine system weight sensitivities for the total range of realistic efficiencies for the respective components.

WBS Number: 2.3.1.4
Orbiter Tasks (Cont)

(7) Determine system weight sensitivities for systems requiring accumulators with respect to important accumulator parameters since accumulators comprise a large proportion of the total system weight of high pressure systems. The system weight sensitivities must be determined to accumulator pressure ratio, accumulator materials, and time response of turbo-machinery, gas generators, and heat exchangers.

(8) Investigate system weight sensitivities to small changes in safety factor, particularly in areas where cycle life cannot be adequately defined.

(9) Define system weight sensitivities for changes in other subsystems which affect ACPS weight (example: low Pc system weight to injection tankage operating pressure).

Optimize the design on weight, cost, critical technology, shuttle IOC, reliability, and simplicity. Appropriate weighting factors shall be determined for each of these factors when applying it to design optimization. Mission flexibility, commonality between booster and orbiter, integration capability, maintainability, system interfaces with the vehicle and other vehicle systems and instrumentation shall also be considered. The system sensitivity studies should provide sufficient insight into each concept to determine whether or not it has sufficient merit to pursue it further in a subsequent preliminary design task.

d. Conceptual Designs

(1) Generate ACPS conceptual configuration and sufficient vehicle installation layout drawings, and recommend to NASA the most promising ACPS candidates, emphasizing minimum new technology, inherent simplicity, low system weight, and flexibility to mission changes.

(2) Identify critical technology areas.

WBS Number: 2.3.1.4
Orbiter Tasks (Cont)

e. Identification of Candidate System Concepts

(1) Identify all promising ACPS concepts to compare during the study. The candidate systems will include both low and high chamber pressure system concepts and will include separate and integrated propellant storage techniques. (Consideration will be given to use of injection and OMS residuals where possible.)

(2) Consider the following techniques for achieving satisfactory system operating pressure:

(a) Direct usage from injection tanks
(b) Pumps
(c) Compressors
(d) High pressure liquid storage
(e) Supercritical storage
(f) Combinations of above

(3) Consider the following techniques for achieving satisfactory thermal conditioning of ACPS propellants:

(a) Thermal heat sink capacity of injection tanks and primary structure
(b) Gas generators and heat exchanger

(4) Define the candidate system concepts in sufficient depth to identify components to be used in the systems and to identify the range of interest of parameters being evaluated.

6. In company-sponsored activity, define reusable shuttle ACPS system evaluation criteria and sensitivities to include the following:

a. System and component performance

b. Weight

c. Cost (commonality - booster and orbiter)

d. Failure mode and effects (redundancy and reliability)

e. System integration

WBS Number: 2.3.1.4
Orbiter Tasks (Cont)

f. Technology and development status and risk

g. Safety and hazards

7. Select ACPS baseline system for preliminary design and document the ACPS trade study. Evaluate ACPS system from Task 3 based upon requirements and criteria of Tasks 2 and 6. Select the baseline ACPS with NASA approval. Prepare ACPS configuration trade study documentation (CS-2.3.1.4-21029).

8. Include in preliminary ACPS design for the baseline system definition the following:

   a. Reevaluate vehicle configurations, mission profile, and control and stability requirements.

   b. Reevaluate propellant usage rates and cooperate with NASA to identify the most suitable control rate accommodation philosophy (minimum versus maximum, engine out), concentrating on the dependence of ACPS system and propellant weight and volume on reaction rate and deadband tolerances.

   c. Reevaluate system performance, operational modes, and maintainability balances, considering operating and nonoperating environment.

   d. From the component definition and sensitivity studies of the conceptual system subtask and the reevaluations (Items a, b, and c), establish component weights, volumes, and operating characteristics.

   e. Identify ACPS instrumentation and discern between cockpit display and flight recorder, and telemetry data requirements.

   f. Perform redundancy and reliability analysis.

   g. Analyze safety and hazards.

   h. Establish system life, thermal control, propellant conditioning, and vehicle interface requirements.

   i. Determine propellant acquisition, storage, pressurization, and distribution requirements, and develop methods of accommodation.

WBS Number: 2.3.1.4
Orbiter Tasks (Cont)

j. Generate detailed thruster and installation design data.

k. Provide preliminary design ACPS configuration and installation layout drawings.

l. Recommend primary ACPS candidate system, emphasizing inherent simplicity, low system weight, minimum new technology required, and flexibility to accommodate vehicle and mission changes.

9. For baseline system definition, prepare system definition document, final report, CEI specification input, technology status, and ACPS test plans data inputs in company-sponsored activity.

10. In company-sponsored activity, coordinate ACPS requirements and study results with customer; coordinate ACPS subcontractor and propulsion vendor data on a timely basis consistant with milestones set forth in Integration Task 1. Coordinate and ensure inclusion of NASA technology study data in the ACPS study activity wherever possible.

WBS Number: 3.3.1.3
Booster Tasks

Company:	Function:	Manager:
GD	Propulsion	A. Schuler

1. Prepare, coordinate, and update orbiter ACPS study plans defining in detail tasks, input data, system requirements, and expected output data. Review and integrate applicable company-sponsored technical study data and methodology into applicable portions of the orbiter ACPS study on a timely basis.

2. Define subsystem requirements and ACPS functions in terms of vehicle/mission constraints. Consideration will be given to the following:

   a. Attitude Control Maneuvers. Translation and rotation.

   b. Physical Features. Geometry, thruster location, and number of thrusters.

   c. System Performance. Minimum impulse bit capability, maximum duration burn, and specific impulse.

WBS Number: 3.3.1.3
Booster Tasks (Cont)

3. Collect and evaluate vendor data for ACPS component performance, physical and design characteristics, cost, and availability. Included will be the available data for thrusters, propellant storage, feed and pumping systems, accumulators, and components such as valves, heat exchangers, gas generators, system controls and instrumentation.

4. Where current vendor data are not available for the components mentioned in Task 5, the required data will be developed in company-sponsored activity by use of available engineering techniques and existing data to provide the best possible estimates.

5. In company-sponsored activity identify and evaluate system concepts for application to the orbiter ACPS.

   a. Conceptual System Definition

      (1) Identify thruster location and thrust levels to provide required linear and angular accelerations for NASA-established minimum, nominal minimum, nominal maximum, and maximum reaction rates (consider, but do not limit to, thruster placement which will allow a single engine for all axes and which is common for booster and orbiter).

      (2) Determine propellant usage rate and quantity for thruster locations and reaction rates for vehicle and systems developed in accordance with Item (1).

   b. System Studies

      (1) Identify propellant sources, and design and operational constraints.

      (2) Synthesize candidate propellant conditioning systems while meeting fail-operational/fail-safe criteria, and identify associated volumetric and weight penalties.

      (3) Refine system analytical models for system sensitivity studies.

   c. System Sensitivities. Determine system balance and optimize components through tradeoffs, concurrently affecting all ACPS components while satisfying vehicle/mission constraints.

WBS Number: 3.3.1.3
Booster Tasks (Cont)

(1) Determine ACPS weight sensitivity to engine chamber pressure and engine O/F ratio for both low and high chamber pressure system.

(2) For systems which require gas generators, determine O/F ratios over the allowable exit temperature range.

(3) When considering sensitivity of system weight to overall O/F ratio, determine the O/F ratio of available residuals for those systems concepts that can utilize available residuals. It is necessary to know the probable residual (or boiloff) O/F ratio before the system weight of those concepts can be optimized with respect to O/F ratio.

(4) For all systems, determine the engine thrust level variation with changes in propellant inlet temperature and pressure and reduce it to tolerable level.

(5) For low-pressure systems determine the system weight sensitivity to distribution lines and component pressure drop.

(6) In systems requiring pumps, compressors, turbines, heat exchangers, etc., determine system weight sensitivities for the total range of realistic efficiencies for the respective components.

(7) Determine system weight sensitivities for systems requiring accumulators with respect to important accumulator parameters since accumulators comprise a large proportion of the total system weight of high pressure systems. The system weight sensitivities must be determined to accumulator pressure ratio, accumulator materials, and time response of turbomachinery, gas generators, and heat exchangers.

(8) Investigate system weight sensitivities to small changes in safety factor, particularly in areas where cycle life cannot be adequately defined.

(9) Define system weight sensitivities for changes in other subsystems which affect ACPS weight (example: low Pc system weight to injection tankage operating pressure).

WBS Number: 3.3.1.3
Booster Tasks (Cont)

Optimize the design on weight, cost, critical technology, shuttle IOC, reliability, and simplicity. Appropriate weighting factors shall be determined for each of these factors when applying it to design optimization. Mission flexibility, commonality between booster and orbiter, integration capability, maintainability, system interfaces with the vehicle and other vehicle systems and instrumentation shall also be considered. The system sensitivity studies should provide sufficient insight into each concept to determine whether or not it has sufficient merit to pursue it further in a subsequent preliminary design task.

d. Conceptual Designs

(1) Generate ACPS conceptual configuration and sufficient vehicle installation layout drawings, and recommend to NASA the most promising ACPS candidates, emphasizing minimum new technology, inherent simplicity, low system weight, and flexibility to mission changes.

(2) Identify critical technology areas.

e. Identification of Candidate System Concepts

(1) Identify all promising ACPS concepts to compare during the study. The candidate systems will include both low and high chamber pressure system concepts and will include separate and integrated propellant storage techniques.

(2) Consider the following techniques for achieving satisfactory system operating pressure:

(a) Direct usage from injection tanks
(b) Pumps
(c) Compressors
(d) High pressure liquid storage
(e) Supercritical storage
(f) Combinations of above

(3) Consider the following techniques for achieving satisfactory thermal conditioning of ACPS propellants.

WBS Number: 3.3.1.3
Booster Tasks (Cont)

(a) Thermal heat sink capacity of injection tanks and primary structure
(b) Gas generators and heat exchangers

(4) Define the candidate system concepts in sufficient depth to identify components to be used in the systems and to identify the range of interest of parameters being evaluated.

6. In company-sponsored activity, define reusable shuttle ACPS system evaluation criteria and sensitivities to include the following:

   a. System and component performance

   b. Weight

   c. Cost (commonality - booster and orbiter)

   d. Failure mode and effects (redundancy and reliability)

   e. System integration

   f. Technology and development status and risk

   g. Safety and hazards

7. Select ACPS baseline system for preliminary design and document the ACPS trade study. Evaluate ACPS system from Task 3 based upon requirements and criteria of Tasks 2 and 6. Select the baseline ACPS with NASA approval. Prepare ACPS configuration trade study documentation (CS-2.3.1.4-21029).

8. Include in preliminary ACPS design for the baseline system definition the following:

   a. Reevaluate vehicle configurations, mission profile, and control and stability requirements.

   b. Reevaluate propellant usage rates and cooperate with NASA to identify the most suitable control rate accommodation philosophy (minimum versus maximum, engine out), concentrating on the dependence of ACPS system and propellant weight and volume on reaction rate and deadband tolerances.

WBS Number: 3.3.1.3
Booster Tasks (Cont)

c. Reevaluate system performance, operational modes, and maintainability balances, considering operating and nonoperating environment.

d. From the component definition and sensitivity studies of the conceptual system subtask and the reevaluations (Items a, b, and c), establish component weights, volumes, and operating characteristics.

e. Identify ACPS instrumentation and discern between cockpit display and flight recorder, and telemetry data requirements.

f. Perform redundancy and reliability analysis

g. Analyze safety and hazard

h. Establish system life, thermal control, propellant conditioning, and vehicle interface requirements.

i. Determine propellant acquisition, storage, pressurization, and distribution requirements, and develop methods of accommodation.

j. Generate detailed thruster and installation design data.

k. Provide preliminary design ACPS configuration and installation layout drawings.

l. Recommend primary ACPS candidate system, emphasizing inherent simplicity, low system weight, minimum new technology required, and flexibility to accommodate vehicle and mission changes.

9. For baseline system definition, prepare System Definition Document, Final Report, CEI specification input, technology status, and ACPS test plans data inputs in company-sponsored activity.

10. In company-sponsored activity, coordinate ACPS requirements and study results with customer; coordinate ACPS subcontractor and propulsion vendor data on a timely basis consistant with milestones set forth in Integration Task 1 (WBS 2.3.1.4). Coordinate and ensure inclusion of NASA technology study data in the ACPS study activity wherever possible.

WBS Number: 3.3.1.3
Booster Tasks (Cont)

Company:	Function:	Manager:
GD	Mass Properties	R. L. Benson

Determine weight, installed center of gravity, installed moment of inertia, material designation, and SP 6004 code. Prepare input for digital computer, review design for optimum weight, and establish target weights for weight control.

SPACE SHUTTLE PHASE B
TASK DESCRIPTION

WBS TITLE: AIRBREATHING PROPULSION SYSTEM

WBS Number: 2.3.1.5
Integration Tasks

Company:	Function:	Manager:
NR	Fluids and Propulsion	R. E. Field

1. Review and evaluate the candidate AB engine selections, for the orbiter and booster, to determine the potential for common engine selection.

2. Review and evaluate initial interfacing AB system, i.e., fuel, air start, controls, etc., for commonality of concepts and hardware for the booster and orbiter. GSE interface requirements will be included in this evaluation.

3. Review and evaluate each system, booster and orbiter ABPS, for compliance with required design criteria.

4. Provide support to NASA technology contracts. Attend integration meetings and provide interface data. Maximize use of technology contract data in Phase B vehicle studies.

5. Define possible techniques of assessing propulsion and mechanical systems integrity by use of integral leak detection systems, sensing parts, instrumentation, component position indications, etc. Define mechanical and propulsion systems checkout intefaces with ground and/or onboard checkout system.

WBS Number: 2.3.1.5
Orbiter Tasks

Company:	Function:	Manager:
NR	Fluids and Propulsion	R. E. Field

Evaluate the results of the company-sponsored airbreathing propulsion systems (ABPS) studies and analyses for application to the contract effort. These studies and analyses include:

1. In company-sponsored activity, evaluate specific engine configuration for space application using hydrogen and JP fuel. Define, in coordination with selected engine contractors, the best compromise configuration for evaluation selection of engines.

2. In company-sponsored activity, evaluate specific engine configuration for space application using hydrogen fuel. Define specific performance

WBS Number: 2.3.1.5
Orbiter Tasks (Cont)

interface requirements and configuration. Define specific development programs, cost, and schedules for both JP and H_2 engines for trade evaluation.

3. In company-sponsored activity, define specific air vehicle fuel system and hardware requirements that are compatible with the candidate JP and H_2 fueled engines defined in Task 2.

4. In company-sponsored activity, in support of air vehicle configuration and vehicle integration trade studies, conduct analysis of proposed engine locations and deployment techniques generated, and define the requirements and configuration of tankage and fuel feed, engine installation, and control requirements to the engine.

5. In company-sponsored activity, define the entry and air-start requirements profile. Evaluate engine windmill start capabilities and start requirements with engine manufacturers. Evaluate assist-start variants, such as mechanical starters (cartridge, air turbine) and impingement starting methods.

6. In company-sponsored activity, define ABPS requirements, considering integrated avionics concepts. Evaluate control, status, and performance monitoring and malfunction detection requirements. Coordinate requirements with engine manufacturers.

7. In company-sponsored activity, prepare installed performance data for engines and fuel systems defined for selection evaluation.

Using the results of applicable company-sponsored studies and analyses, conduct contractural trade studies and analysis as follows:

8. Conduct trade study of H_2-versus-JP airbreathing engine. Effort will include comparison of the requirements of H_2 and JP vehicle fule system and engine modifications relative to impact on total system weight, cost, development time, and complexities. Document results and recommended system for NASA review.

9. Conduct trade study and analysis for powered-versus-unpowered orbiter landing trade study. Identify airbreathing engine size and installation requirements and the fuel system requirement for powered landing configuration variants. Evaluate aerodynamic sophistications required for unpowered variant. Compare variants impact on system weight, cost, orbiter payload, and booster configuration. Document results and recommended system variant for NASA review.

WBS Number: 2.3.1.5
Orbiter Tasks (Cont)

10. If an unpowered configuration is selected, define in detail the configuration and requirements for air-breathing propulsion ferry kit.

11. Conduct supporting studies and analysis for self-ferry capability trade study. Determine alternative engine size and installation, and auxiliary fuel system for various configuration studies. (In support of Task 2.1.10)

12. Coordinate space and ferry environment and operational requirements with airbreathing engine contractors to determine impact on candidate engine design (modification), development effort, cost, and schedule.

13. Evaluate results of engine selection studies and results of trade studies, Items 1, 2, and 3. Document engine requirements and duty cycle in Propulsion Tradeoff Report DRD SE003M. In support of trade studies and configuration definition, conduct failure modes and affects analysis.

14. Review results of system trade studies and analysis with NASA. Define detail configuration and requirements for engines, inlet, fuel, start, control, and instrument system for preliminary design definition.

15. Identify and classify potential hazards, and analyze safety operation modes for airbreathing propulsion system.

16. Provide preliminary inputs to the Systems Definition Handbook, ICD's, CEI specifications, and test plans.

17. Provide details of all engine components, engine installation, fuel system and allied propulsion subsystems for interim airbreathing propulsion design drawings. Update and refine propulsion details for preliminary design definition and drawing.

18. In company-sponsored activity, prepare finalized concept schematics for the engine installation, fuel system, and allied propulsion subsystems, illustrating detailed system concepts and operation.

19. In company-sponsored activity, prepare finalized propulsion system data for the Systems Definition Handbook.

20. In company-sponsored activity, prepare planning documents for the Phase C proposal, work breakdown schedules, and task descriptions.

21. In company-sponsored activity, prepare inputs for preliminary equipment specifications for the airbreathing system.

WBS Number: 3.3.1.4
Booster Tasks

Company:	Function:	Manager:
GD	Propulsion	A. Schuler

Conduct and support trade studies of the booster airbreathing propulsion system to determine propellant type, booster requirements, and system installation and configuration definition.

1. Conduct trade study of H_2-versus-JP airbreathing engines to evaluate the feasibility of using hydrogen for booster airbreathing engine fuel and compare the results with those for JP fuel (CS-2.3.1.4-61004).

2. Conduct an airbreathing engine installation and configuration trade study (CS-2.3.1.4-61008) to define the type and thrust level of the ferry, go-around, or landing-assist engines, including performance, pressurization, lubrication system, instrumentation, data display, location, tankage and fuel feed, deployment techniques, and control requirements of the engine. Define the environmental exposure for the airbreathing engines.

3. In company-sponsored activity, define the self-ferry capability requirements for the booster. Establish ferry range and vehicle characteristics for available and advance technology engines. Integrate ferry capability requirements with flyback mission requirements and provide recommended system configuration.

4. In company-sponsored activity, perform engine selection analysis and make recommendations for booster engine choice. Evaluation criteria will include performance, cost, and development time and risk. Definition of engine requirements and duty cycle will be accomplished.

5. In company-sponsored activity, analyze vehicle and mission requirements to define the engine environmental requirements. Establish vibration, loads, pressure, and temperature levels for the booster engines. Evaluate environmental incompatibilities, and recommend vehicle or engine solutions.

6. In company-sponsored activity, evaluate engine air-start requirements and capabilities with the engine manufacturers. Perform trade analysis of windmill starts and assist start options such as mechanical starters and impingement starters. Provide recommendations for consideration in preparation of engine requirements and CEI documents.

WBS Number: 3.3.1.4
Booster Tasks (Cont)

7. In company-sponsored activity, study engine/vehicle integration to establish engine control, checkout, instrumentation, and data display interfaces with the vehicle integrated electronics and to integrate the fuel feed system and engine installation interfaces with the vehicle mechanical systems. Coordinate requirements, and interface with engine manufactures.

8. In company-sponsored activity in support of trade studies and configuration definition, conduct failure mode and effects analysis. Critical components will be identified for redundancy considerations.

9. Establish booster airbreathing propulsion design requirements and configuration based on contractor and customer evaluation of trade study and analysis results.

10. Identify and classify potential hazards, and analyze safety operation modes for airbreathing propulsion system.

11. Provide details of all engine components, engine installation, fuel system, and allied propulsion subsystems for interim airbreathing propulsion design drawings. Update and refine propulsion details for preliminary design definition and drawing.

12. In company-sponsored activity, prepare finalized concept schematics for the engine installation, fuel system, and allied propulsion subsystems, illustrating detailed system concepts and operation.

13. In company-sponsored activity, prepare finalized propulsion system data for the Systems Definition Handbook.

Company:	Function:	Manager:
GD	Mass Properties	R. L. Benson

Determine weight, installed center of gravity, installed moment of inertia, material designation, and SP6004 code. Prepare input for digital computer, review design for optimum weight, and establish target weights for weight control.

SPACE SHUTTLE PHASE B
TASK DESCRIPTIONS

WBS TITLE: STORAGE TANK SYSTEM

WBS Number: 2.3.1.6
Integration Tasks

Company:	Function:	Manager:
NR	Fluids and Propulsion	R. E. Field

Through coordinated efforts among NASA, NR SD, and GD/Convair, achieve commonality of cryogenic tankage system materials, components, and subsystems between the shuttle orbiter and booster. Special emphasis will be placed on the main propulsion tanks: (1) insulation selection and installation placement and (2) pre- and post-launch insulation purge concepts. Special emphasis will be placed on the tankage system GSE and safing requirements.

1. Provide support to NASA technology contracts. Attend integration meetings and provide interface data. Maximize use of technology contract data in Phase B vehicle studies.

2. Define possible techniques of assessing propulsion and mechanical systems integrity by use of integral leak detection systems, sensing parts, instrumentation, component position indications, etc. Define mechanical and propulsion systems checkout interfaces with ground and/or onboard checkout systems.

WBS Number: 2.3.1.6
Orbiter Tasks

Company:	Function:	Manager:
NR	Fluids and Propulsion	R. Field

Establish cryogenic tankage system conceptual design and operational characteristics of (1) the orbit maneuvering, aribreathing, and ACPS propellant tankage for storage, location control, conditioning, venting, and gauging of LO_2 and LH_2 in space for 30 days and (2) the cryogenic thermal protection system for the main propulsion, APU, ECLSS, and fuel cell tanks. The following tasks apply to the contract effort:

1. <u>Candidate Orbit Maneuvering, Airbreathing, and ACPS Tankage System Concepts.</u> Identify, by means of schematics and pictorial descriptions,

WBS Number: 2.3.1.6
Orbiter Tasks (Cont)

subsystem alternatives for the orbit maneuvering, airbreather, and ACPS cryogenic tankage. The following subsystem and component concepts and alternatives will be included in the study:

a. High-performance insulation (HPI) types to be considered: GAC-9 (Goodyear), DAM/NM, DAM/Tissuglas, SUPERFLOC (GD/Convair), and NARSAM (NR SD).

b. HPI atmospheric isolation by means of (1) a dewar concept and (2) a gas evacuation/repressurization concept.

c. Minimum heat-leak tank supports consisting of titanium, boron-epoxy, or fiberglas-epoxy materials.

d. Plumbing heat-blocks consisting of fiberglas wound 2-mil-thick stainless steel liner, insulated titanium tubular section, or insulated stainless steel tubular section.

e. Propellant zero-g venting by means of (1) a semi-passive thermodynamic NR SD concept or (2) an active thermodynamic GD/Convair concept.

f. Regenerative cooling with H_2 boiloff to attain LO_2 zero boiloff loss.

g. Propellant thermal destratification by (1) an ullage thermodynamic conditioning process and (2) a liquid mechanical mixing process.

h. Zero-g propellant location control by means of capillary retention screens, cruciform capillary collector plates, capillary pump channels, bubble isolation/expulsion screens, and disk barriers.

2. Candiate Main Propulsion Cryogenic Thermal Protection Concepts. Identify, by means of schematics and pictorial descriptions, cryogenic thermal protection subsystem definitions for the main propulsion system LO_2 and LH_2 tankage. The following subsystem and component concepts and alternatives will be included in the study:

a. Insulation for LH_2 tankage to be mounted to the internal or external surface of the tank wall with materials and constructions based on (1) the seal concept or (2) the gas layer concept.

b. Cryogenic thermal protection for LO_2 tankage to be accomplished with a nitrogen gas layer immediately adjacent to (1) a noninsulated tank wall and (2) a closed cell polyurethane foam insulated tank wall (externally mounted).

WBS Number: 2.3.1.6
Orbiter Tasks (Cont)

c. Pre- and post-launch cryogenic insulation purge systems (1) integral and (2) nonintegral with the vehicle thermal protection system.

3. Baseline/Alternate Concept Selection. Perform parameteric tradeoff analyses and evaluations of subsystem performance, weight, and complexity to narrow selections of candidate subsystems to one baseline plus not more than one alternative for each of the main propulsion, orbit maneuvering, airbreather, and ACPS tankage systems. Reusability will be a design goal relative to accessibility, reliability, cycle life, etc.

4. Baseline/Alternate 30-Day Tankage System Analysis. For the 30-day cryogenic storage tanks, accomplish the following objectives with respect to the selected baseline and alternate cryogenic subsystems:

   a. Functional integrity of each subsystem consistent with operational constraints and requirements imposed by the vehicle and interfacing subsystems.

   b. Interface requirements.

   c. Component sizing, weight, and power requirements.

   d. Leakage rates and isolation provisions.

   e. Definition of critical developmental items.

   f. Extent of propellant thermal stratification during launch.

   g. Abort mission capabilities.

   h. Residual propellant quantities.

5. Baseline/Alternate Main Propulsion Tanks System Analysis. For the main propulsion tanks, perform the following subtasks on the selected baseline and alternate cryogenic thermal protection systems:

   a. Conduct tradeoff studies of internal versus external insulation placement on the main LH_2 tanks.

   b. Establish insulation type and mount for LH_2 and LO_2 tanks.

   c. Establish insulation purge and evacuation system conceptual design for LO_2 main tank.

   d. Coordinate efforts with GD on similar requirements of the shuttle boost vehicle.

WBS Number: 2.3.1.6
Orbiter Tasks (Cont)

e. Establish the extent of thermal stratification in LH_2, during atmospheric ascent.

f. Establish conceptual design for a system to provide rapid H_2 dump before landing.

6. Combined Tankage Study. Establish the practicality of using the same tankage for ACPS and fuel cells; orbit maneuvering propulsion and ACPS; or orbit maneuvering propulsion and airbreathing propulsion.

7. Residual Propellant Recovery Study. Establish and analyze a conceptual design for recovering main propulsion tank residuals for ACPS and/or orbit maneuvering propulsion.

8. Subsystems Evaluation. Conduct an evaluation of subsystem candidates based on a grade-rating technique involving a measure of performance, reliability, weight, servicing cost, maintainability, reusability, inspectability, status of current technology, and safety.

9. Design Requirements. Establish specific design requirements for each cryogenic tankage system and its subsystems.

10. Support Group Coordination. Coordinate with support groups and direct preliminary design, flight technology, vehicle structures, testing, and manufacturing as necessary to formulate preliminary designs for the cryogenic tankage subsystems. The following specific efforts will be accomplished in Tasks 4, 9, and 10 on the subassemblies as indicated.

a. Propellant Acquisition and Storage

(1) Determine the method of loading propellants
(2) Determine the method of propellant egress from ACPS storage
(3) Determine the means of ACPS propellant storage
(4) Define the method or methods of propellant positioning (if necessary)

b. Propellant Pressurization and Conditioning

(1) Determine method of pressuring propellants
(2) Determine need for and method of propellant conditioning

WBS Number: 2.3.1.6
Orbiter Tasks (Cont)

(3) Define power requirements

(4) Determine the required operating duty cycles

(5) Define methods of waste gas disposal

(6) Define stable operating regimes

c. Propellant Distribution

(1) Determine thermal control requirements

(2) Define feed system stability and dynamics characteristics

11. Liaison. Perform customer and subcontractor liaison.

12. NR SD Manufacturing and Test. Define constraints, capabilities, and development inpacts to NR SD Manufacturing and to NR SD Laboratories and Test.

13. Engineering Support. Provide support for the following tasks and codumentation:

a. Support research and technology (SRT) in accordance with DRD MA022M

b. CEI specifications

c. System Data Handbook (SDH) DRD SE004M

d. Phase B final report per DRD MA016M

e. FMEA and hazards analysis inputs

f. Subsystem measurement and control requirements

WBS Number: 2.3.1.6
Orbiter Tasks (Cont)

14. Related Company-Sponsored Efforts. Evaluate and use, where applicable to the contract, the results of the following company-sponsored efforts: In company-sponsored activity, establish propellant subsystems for cryogenic propellant tankage which are low cost, practical, and reliable; require minimum development; and are well suited to requirements of reusable space vehicles. Identify critical technology areas; develop subsystem design and analysis techniques and tradeoff data; and demonostrate reusability and cryogenic hydrogen long-duration storage capability by means of large-scale tankage system tests. Following are specific tests set forth to accomplish these objectives.

    a. Thermodynamic Vent System. Develop analysis capability for designing LH_2 tankage zero-g thermodynamic vent systems, and perform tradeoff analysis against candidate thermodynamic vent system concepts.

    b. LO_2 Regenerative Cooling System. Develop analysis capability for designing a LO_2 tank regenerative cooling subsystem for zero-boiloff loss of LO_2 on long-duration space storage applications. The LO_2 regenerative cooling system will be coupled to, and properly interfaced with, the LH_2 thermodynamic vent system with LH_2 boiloff used as the regnerative cooling system coolant. Perform tradeoff analysis against candidate regenerative cooling system concepts.

    c. HPI Air Isolation Concept. Establish candidate designs for isolating high-performance insulation from air for LO_2 and LH_2 tanks which must be reusable through repeated atmospheric ascent and descent operations. Complexity versus weight for a dewar versus a gas evacuation concept will be included in the study.

    d. Cryogenic Thermo-hydrodynamic Analysis. Develop analysis capability for predicting the thermo-hydrodynamic behavior of LO_2 and LH_2 (1) stored in space for long durations under low-g and zero-g conditions and (2) stored on the ground for 60 hours during ground hold without boiloff loss. Conduct tradeoff analysis of tank pressure rise versus affecting parameters.

    e. Capillary Retention/Pump System. Conceptualize design and analyze capillary retention/pump subsystem for LO_2 and LH_2 long-term space storage application. Extend and improve design analysis capability to include cryogenic-thermal effects of LH_2 and LO_2

WBS Number: 2.3.1.6
Orbiter Tasks (Cont)

cryogens. Conduct experimental investigations to improve analysis capability and to provide design feasibility.

f. Zero-G Propellant Gauging. Review latest zero-g gauging concepts and formulate preliminary selection of candidate subsystems with a tradeoff review of their advantages and disadvantages to long-term/high-endurance applications. Conceptualize a capacitance gauging system as an integral part of the capillary barrier propellant location control subsystem, and coordinate effort with outside contractors to establish feasibility.

g. Cryogenic Tankage System Test. Demonstrate, by large-scale cryogenic hydrogen space thermal-vacuum tests on a total tankage system, the capability of a NR SD hydrogen tankage system to efficiently store and thermodynamically vent LH_2 for 30 days in space before and after undergoing cyclic simulations of ascent and descent atmospheric pressure and thermal environments.

In company-sponsored activity, provide NASA with critical technology requirements and proposed solutions pertaining to space shuttle long-term cryogenic tankage systems. NASA is to be presented with the latest NR SD conceptual designs for cryogenic thermal protection; LH_2 thermodynamic venting; LO_2 regenerative cooling; gauging; and propellant conditioning, location control, and destratification. A large-scale cryogenic tankage system space simulation thermal-vacuum test for evaluating a NR SD high-performance insulation concept employing the NR SD NARSAM insulation will be specifically emphasized together with a LH_2 thermodynamic venting system.

WBS Number: 3.3.1.5
Booster Tasks

Company:	Function:	Manager:
GD	Propulsion	A. Schuler

Establish booster cryogenic tankage system designs and operation characteristics of the ACPS tankage and cryogenic thermal protection system for the main propulsion and flyback propulsion systems' tanks.

WBS Number: 3.3.1.5
Booster Tasks (Cont)

1. Identify, by means of schematics and pictorial descriptions, subsystem alternatives for the ACPS cryogenic tankage. The following subsystems and component cencepts and alternatives will be included in the study:

    a. High-performance insulation (HPI) types to be considered: GAC-9 (Goodyear), DAM/NM, DAM/Tissuglas, SUPERFLOC (GD/Convair), and NARSAM (NR-SD).

    b. HPI atmospheric isolation by means of (1) a dewar concept and (2) a gas evacuation/repressurization concept.

    c. Minimum heat-leak tank supports consisting of titanium, boron-epoxy, or fiberglaslepoxy materials.

    d. Plumbing heat-blocks consisting of fiberglas would 2-mil-thick stainless steel liner, insulated titanium tubular section, or insulated stainless steel tubular section.

    e. Zero-g propellant location control by means of capillary retention screens, cruciform capillary collector plates, capillary pump channels, bubble isolation/expulsion screens, and disk barriers.

2. Identify, by means of schematics and pictorial descriptions, cryogenic thermal protection subsystem definitions for the main propulsion system LO_2 and LH_2 tankage, and airbreathing LH_2 tankage. The following subsystem and component concepts and alternatives will be included in the study:

    a. Insulation for LH_2 tankage to be mounted to the internal or external surface of the tank wall with materials and constructions based on (1) the seal concept or (2) the gas layer concept.

    b. Cryogenic thermal protection for LO_2 tankage to be accomplished with a nitrogen gas layer immediately adjacent to (1) a noninsulated tank wall and (2) a closed cell polyurethane foam insulated tank wall (externally mounted).

    c. Pre- and post-launch cryogenic insulation purge systems (1) integral and (2) nonintegral with the vehicle thermal protection system.

WBS Number: 3.3.1.5
Booster Tasks (Cont)

3. Perform parametric tradeoff analyses and evaluations of subsystem performance, weight, and complexity to narry selections of candidate subsystems to one baseline plus not more than one alternative for each of the main propulsion, airbreather, and ACPS tankage systems.

4. For the main propulsion tanks, perform the following subtasks on the selected baseline and alternate cryogenic-thermal protection systems:

   a. Conduct tradeoff studies of internal versus external insulation placement on the main LH_2 tanks.

   b. Establish insulation type and amount for LH_2 and LO_2 tanks.

   c. Establish insulation purge and evacuation system conceptual design for LO_2 main tank.

5. Establish the practicality of using the same tankage for ACPS and APU.

6. Establish and analyze a conceptual design for recovering main propulsion tank residuals for ACPS APU.

7. Conduct an evaluation of subsystem candidates based on a grade rating technique involving a measure of performance, reliability, weight, servicing costs, maintainability, reusability, inspectability, status of current technology, and safety.

8. Establish specific design requirements for each cryogenic tankage system and its subsystem.

SPACE SHUTTLE PHASE B
TASK DESCRIPTIONS

WBS TITLE: ELECTROMECHANICAL INTEGRATED AVIONICS

WBS Number: 2.3.2
Integration Tasks

Company	Function:	Manager:
NR	Integrated Avionics	G. C. Anderson

Control and monitor IAS development, assisted by General Dynamics as discussed in the following IAS subsections. Technical guidance and control for IAS subcontractors will emanate from NR for overall system and/or orbiter-unique functions and from GD/Convair for booster-unique functions. All efforts will be coordinated through the NR area with prime responsibility as shown in Table 2.3.2. One or more full-time representatives from both IBM and HI will be on site at NR throughout the conduct of the Phase B study effort to ensure direct technical coordination for all subcontractor effort. A full-time NR Avionics representative, reporting to the Manager, IAS, will be on site at GD/Convair to ensure a direct technical link between NR/GD effort.

Overall integration responsibility for IAS subsystem elements is assigned to the Manager of the IAS subsystem and will be effected through an Integration, Checkout, Displays, and Controls group.

WBS Number: 2.3.2
Orbiter Tasks

Company:	Function:	Manager:
NR	Integrated Avionics	G. C. Anderson

1. Establish preliminary performance characteristics for the EM/IAS. Devise equipment interface parameters, including weight, power, volume, form, environment control requirements, and signal characteristics, including type, level, timing, etc. Establish subsystem and software cost and schedule impacts and support research and technology requirements. Prepare subsystem and software performance and interface specifications to include technical data for preliminary specifications and for ICD's.

2. Provide safety data to support a system safety analysis for all aspects of the EM/IAS, including prelaunch, launch, abort and recovery, range safety, in-orbit safety, escape and rescue, and recovery missions. Identify and classify potential and inherent hazards. Conduct safety

analysis. Provide detailed description of identified hazards, and prepare hazard analysis sheet. Define safety considerations. Include identification of safety assumptions, documentation of safety rationale, evaluation of influence of assumptions, and identification and documentation of residual hazards.

3. Provide inputs in support of failure mode and Effects Analysis (FMEA), including requested data in columns 1, 5, 6, and 10 on the FMEA form for each major function in the applicable subsystem. Support reliability in preparation of logic diagram at the subsystem level.

4. Support the booster Phase B effort to the extent required to assure suitability of the EM/IAS for common usage in orbiter and booster where vehicle and mission requirements are essentially the same; timely availability to GD of information developed; and definition of EM/IAS differences resulting from unique booster requirements.

5. Major Trade Studies

   a. Centralization of Functions. Define degree of centralized computational function versus dedicated distributed.

   b. Digital Interface Techniques. Compare data bus techniques — multiplexed/non-multiplexed.

   c. Avionics Modular Design. Determine degree of modularization/packaging techniques.

   d. Power Condition, Conversion, Distribution, and Control. Establish power types/quality and distribution techniques.

   e. Onboard Checkout Techniques. Determine optimum onboard checkout/fault isolation techniques.

   f. Configuration and Sequencing Control. Determine optimum balance between onboard automatic/manual control.

   g. Redundancy Techniques. Select optimum redundancy techniques. Study FO-FO-FS.

   h. Integrated Displays and Controls. Determine optimum man/machine interface techniques.

Table 2.3.2. Areas of Responsibilities, Space Shuttle Phase B Study

Area	Responsibilities	WBS Identification
Checkout, Integration, Displays, and Controls (CIDC)	IAS system integration, checkout/fault isolation technique, ground interfaces, instrumentation, caution and warning, displays and controls concepts, panel configuration functions, and related trade studies. (Responsible for technical guidance and control of all IBM-related effort.)	2.3.2.1, 2.3.2.4, and 2.3.2.8
Data and Control Management (DCM)	Data transmission techniques, computer configuration, data bus/system interfaces, required software, and related trade studies. (Responsible for technical guidance and control of all IBM effort related to DCM.)	2.3.2.2 and 2.3.2.7
Guidance, Navigation, and Control (GN&C)	GN&C system configuration, including flight controls and flight control simulations. (Responsible for technical guidance and control of all HI effort.)	2.3.2.3 and 2.3.9
Communications (COMM)	Overall space/ground communication system, including antennas, conventional aircraft landing, and navigation equipment and related trade studies.	2.3.2.5
Power Conditioning and Control	Power distribution system configuration, system schematic diagrams, lighting systems/techniques, avionic equipment installation concepts/design, and related trade studies.	2.3.2.6

WBS Number: 2.3.2
Orbiter Tasks (Cont)

i. Integrated Sensors and Actuators. Achieve maximum function/equipment commonality consistent with required interface flexibility for existing sensors and actuators.

j. Integrated versus Conventional Avionics. Compare cost, weight, performance, complexity, etc.

k. Shuttle and Ground Communication Interfaces. Select and define optimum shuttle/ground communication system.

6. Other Studies

a. Autopilot Study. Determine optimum configuration for flight control fail-safe mechanization.

b. On-orbit Navigation Study. Determine optimum update techniques.

c. Checkout Fault Isolation. Determine optimum interface and techniques for handling and storing data consistent with DCM system.

d. Displays and Controls. Determine type and number of displays, requirement for heads-up displays (HUD), control number and location requirements, etc.

e. Guidance/Navigation/Flight Controls. Determine optimum techniques, calibration methods, etc.

f. Communications. Determine antenna types and locations, data and voice modulation techniques, approach and landing aids, etc.

g. Electromagnetic Interference. Determine standards, control criteria, verification testing requirements, etc.

h. Radiation Survivability. Determine cost and equipment considerations for survivability of electronic equipment.

i. Software. Determine control and integration techniques to minimize cost and complexity.

WBS Number: 3.3.2
Booster Tasks

Company:	Function:	Manager:
GD	Integrated Avionics	C. E. Grunsky

1. Support NR in the development effort for the overall shuttle IAS with emphasis on commonality. Provide and coordinate technical guidance and control for overall system development for unique booster IAS requirements with the NR IAS manager.

2. Assist NR in effecting overall system integration and accomplish unique system integration tasks to support booster development.

3. Identify, define, control, and coordinate unique booster IAS requirements with NR/IBM and/or HI, as required.

SPACE SHUTTLE PHASE B
TASK DESCRIPTIONS

WBS TITLE: SUBSYSTEM INTEGRATION

WBS Number: 2.3.2.1
Integration Tasks

Company:	Function:	Manager
NR	Integrated Avionics	G. C. Anderson

1. Establish the overall integrated avionics system performance requirements considering total program and mission requirements. Define relationship between IAS and requirements of other vehicle subsystems and ground operations that affect cost, schedule, safety, and mission effectiveness. Develop evaluation criteria and plan their application to trade study and other technical decisions having program level impact, employing standard evaluation techniques established by System Engineering.

2. Define the degree of commonality to be achieved in orbiter and booster hardware and software. Record the degree, reflected in the baseline configuration; develop criteria for evaluating all potential configuration changes affecting commonality; and coordinate commonality changes at the program level.

3. Define redundancy policy and candidate methods for IAS, and publish guidelines for use in implementing this policy in Phase B studies. Assure that redundancy policy study results are evaluated for total program effect.

4. Coordinate and maintain a dependency matrix and schedule showing major inputs and outputs for tasks within IAS performed by NR, GD, IBM, or HI, and between subsystem groups for interrelated tasks.

5. Identify areas where research and technology studies are needed to advance the technological areas related to the IAS. Conduct required coordination and planning to initiate these efforts. Develop program guidelines for use in IAS to evaluate technical risk factors.

6. Submit IAS baseline configuration technical descriptions for inclusion in the System Definition Handbook. Monitor all prospective configuration changes; evaluate changes for validity before they are submitted to ERB for consideration as a configuration change.

WBS Number: 2.3.2.1
Integration Tasks (Cont)

7. Provide technical and management control of study activities affecting the IAS baseline configuration. Study results in the areas of commonality, redundancy, cost, and schedule will be reviewed by an internal IAS Review Board (IASRB) before submittal to ERB. This board will include representatives of NR, GD, IBM, and HI. One of the primary objectives of the IASRB will be to control the baseline and final system/subsystem configuration and to ensure commonality between the orbiter and booster avionics. A common orbiter/booster avionics configuration, developed jointly by NR and GD, will serve as a baseline for both vehicles.

WBS Number: 2.3.2.1
Orbiter Tasks

Company:	Function:	Manager:
NR	Integrated Avionics	G. C. Anderson

1. Perform the task of integrating the functions and requirements of the orbiter electromechanical and integrated avionics subsystem, (EM/IAS) which includes GN&C, communications, data and control management, onboard checkout, integrated displays and controls, software, and power distribution and controls.

2. Maintain a single top orbiter IAS control document that defines a current baseline subsystem configuration. Include an overall schematic, to the functional assembly level, reference descriptions from the SDH, and written rationale for the configuration selection.

3. Review all IAS study results for impact on the configuration baseline, and interface with all other Engineering groups on matters affecting the configuration. Incorporate configuration changes after ERB approval.

4. Establish mission impacts, identify critical failure modes (FMEA's), define hardware and software interfaces, establish and define IAS and vehicle subsystem interfaces, and establish function characteristics and functional block diagrams of concepts for the overall IAS.

5. Establish preliminary performance characteristics. Device equipment interface parameters including weight, power, volume, form, environment control requirements, and signal characteristics, including type, level, timing, etc. Establish subsystem and software cost and schedule impacts and support research and technology requirements. Prepare

subsystem and software performance and interface specifications to include technical data for system specifications and ICD's.

6. Provide safety data to support a system safety analysis for all aspects of the EM/IAS, including prelaunch; launch, abort and recovery; range safety, in-orbit safety, escape and rescue, and recovery missions. Identify and classify potential and inherent hazards. Conduct safety analysis. Provide detailed description of identified hazards, and prepare hazard analysis sheet. Define safety considerations. Include identification of safety assumptions, documentation of safety rationale, evaluation of influence of assumptions, and identification and documentation of residual hazards.

7. Support the booster Phase B effort to the extent required to assure suitability of the EM/IAS for common usage in orbiter and booster where vehicle and mission requirements are essentially the same, timely availability to GD of information developed, and definition of EM/IAS differences resulting from unique booster requirements.

8. Utilize the results of the five system level trade studies in this WBS, the additional trade studies and analyses in subsequent IAS WBS descriptions, and data provided from other sources (including NASA) to accomplish the following. Determine the amount of onboard control and automation which is both desirable and feasible, taking into consideration overall subsystem and system concepts, requirements, and crew integration. Investigations and tradeoff studies of crew size and skills, workload, system complexity, checkout and inflight status monitoring, and costs shall be included in determination of the amount of onboard control and automation.

9. Perform the following trade studies. Effort related to specific avionics subsystems will be accomplished by the NR, GD, IBM, or HI organization responsible for the subsystem being studied. IAS system-level integration of trade study results will be performed by NR and GD.

   a. Avionics Modular Design Study

      (1) Objectives. Select proper degree of "black box" standardization and commonality of hardware for all IAS subsystems. Establish physical characteristics of IAS equipment. Establish concept for sub-LRU maintenance and checkout type of circuitry.

WBS Number 2.3.2.1
Orbiter Tasks (Cont)

(2) Description. Consider the following for the IAS: the degree of modularity for both avionics packaging and package installation; standard techniques for packaging, mounting, cooling, interconnections, circuit design, and parts selection; and modular checkout and maintenance approaches. The tasks will include the following effort with regard to avionics packaging and installation.

(a) LRU Data. List of functions, identification of functions, LRU count (total volume), power dissipation, and technology influence on packaging.

(b) Vehicle Data. Obtaining drawings of vehicle allocated volumes and form factors; obtaining data on volume environments; and invent candidate installations.

(c) Installation Trades. Volume/form factor trades, intercabling, cooling methods, and ease of access for each installation.

(3) Study Approach. Develop environmental and structural constraints for evaluation of both the orbiter and booster. Pressurized versus unpressurized sections will receive special emphasis along with high vibration areas such as main propulsion engine compartment. The necessity for access to avionics packages while the vehicles are in a vertical position on the launch pad will then be established. Requirements dictated by redundancy management and onboard checkout considerations will be established. Checkout considerations will center on allocation of functions to facilitate testing onboard the vehicles.

From the results of these investigations, develop and evaluate alternate approaches for LRU level packaging, mounting, cooling, and interconnections. Factors that will be considered are as follows: coldplate versus convection cooling, modified ARINC or custom, rack versus box mount, and flat cable versus round.

The second portion of the study will be concerned with sub-LRU (SRU and smaller) modularization. The effectiveness of standardization of common functions and interconnections will be evaluated along with checkout and maintenance of circuit modules.

WBS Number: 2.3.2.1
Orbiter Tasks (Cont)

b. Configuration and Sequencing Control Study

(1) Objectives. Support definition of the vehicle operations management concept. Support determination of the optimum degree of IAS automation. The study will evaluate vehicle/subsystem requirements for control of sequencing and configuration scheduling, and establish recommended techniques and levels of control. It will also develop criteria for apportionment of vehicle control and subsystem management tasks between crew (manual) and equipment (automatic) functions.

(2) Description. Develop data for evaluation of sequencing and configuration scheduling requirements for the booster and orbiter, and for establishing recommended sequencing and configuration control techniques. Determination of the optimum degree of crew participation in these operations is a major factor. Recommended levels of control will be established.

Analyze sequence and control functional requirements and determine methods of manual and automatic implementation. The need for one man emergency operation will be considered. Three alternatives for integrated configuration and sequence control will be considered: All automatic, crew management and automatic, and manual.

Primary evaluation criteria such as cost, weight, and power will be weighted heavily to emphasize the program goals. Safety is recognized to be of prime importance.

(3) Study Approach. Assemble the requirements for the configuration and sequencing control tasks. Consider complete automatic control for the booster in conjunction with the unmanned versus manned booster trade study. The orbiter will always be manned but as much automatic operation as possible is desirable. Manual override and backup will be provided for safety of flight functions. The crew management and automatic alternative of implementation will require crew participation in significant decisions required during the mission. The manual method of implementing configuration and sequencing controls would emphasize and require crew participation. The limit on the degree of manual control will be the requirement for vehicle operation by one man.

WBS Number: 2.3.2.1
Orbiter Tasks (Cont)

Develop evaluation criteria for analysis of each of the alternate concepts such that each configuration and sequencing control task is handled independently to allow combining manual and automatic techniques of implementation.

Select the most promising approach based on the weighting of the evaluation criteria. An attempt will be made to alter the most promising approach by replacing tasks which appear to penalize the selected approach.

Documentation will include a description of the implementation of each configuration and sequencing control task for each of the three alternate implementation methods. These descriptions will be to the detail determined during the trade study. The justification for the weighting of the evaluation criteria will also be described along with a description of the evaluation process including data used in the selection of the most promising approach.

c. Redundancy Techniques Study

(1) Objectives. Support definition of the IAS concept for fault tolerance and redundancy management. The study will establish IAS fault tolerance rationale and redundancy policy consistent with the mission/vehicle requirements; evaluate candidate redundancy types, levels, and methods of management and define recommended techniques for satisfying the FO-FO-FS criterion; identify promising areas for reduction of complexity in redundant equipment and failure management provisions, i.e., reduced with respect to FO-FO-FS; develop criteria for apportionment of redundancy management tasks between crew (manual) and equipment (automatic) functions; and develop crew safety flight criteria for application to selection of redundancy techniques.

(2) Description

(a) Analyze and evaluate mission and system requirements to establish fault tolerance rationale/criteria and redundancy policy for IAS, its subsystems and interfaces, consistent with FO-FO-FS criteria.

WBS Number: 2.3.2.1
Orbiter Tasks (Cont)

(b) Survey and evaluate candidate redundancy types; levels of application; and methods of management (voting, independent/parallel, etc.), for each typical IAS application category. Define interface requirements for coupling of IAS elements to non-avionic equipment. Define monitoring requirements for annunication of failures, and emergency conditions. Develop fault tolerance rules and guidelines for software development and system verification activities.

(c) Analyze and evaluate the potential and effects of reduced complexity of IAS redundancy with respect to the baseline configuration. Establish the complexity deltas between existing techniques, FO-FS and Fo-Fo-FS.

(d) Evaluate failure management of requirements and recoommended concepts to develop criteria for apportionment of failure management tasks between crew (manual) and equipment (automatic) functions.

(3) Study Approach. Develop data for the study which will resolve redundancy structure, techniques, and methods of management to be recommended both for overall IAS and its component subsystems and equipment. The baseline approach will be used as the reference for impact and effectiveness comparisons involving alternate approaches. The principal goal of the study will be to arrive at the most efficient and cost-effective methods for satisfying shuttle mission/vehicle fault tolerance requirements and objectives.

Analyze redundancy requirements, taking into account not only the IAS hardware but also supporting services, including signal transmission, electrical power, cooling, and interconnection provisions. Design provisions to prevent subsystem equipment faults from propagating into these main services, or damaging connected or contiguous equipment, will receive emphasis in this study.

Redundancy structure and management techniques established by this study will be consistent with fault detection requirements for onboard checkout and with overall philosophies for flight crew management of the vehicle and subsystems.

WBS Number: 2.3.2.1
Orbiter Tasks (Cont)

d. Integrated Sensors and Actuators

(1) Objectives. Support definition of the IAS concept for interface between central data management and existing or planned subsystem hardware. The study will define DCM system/subsystem interface criteria and recommended interface techniques for the various application categories. Consideration will be made to the modification of existing hardware to adapt the hardware to the Data Bus or providing standardized adapter units. Criteria for safety of flight (SOF) or mission critical functions will be defined to determine which functions should be integrated with the central data and command/control function and which should remain independent.

(2) Description

(a) Analyze elements of other subsystems which interface with IAS and IAS subsystem elements which transmit data or receive command signals via the main data bus to develop interface criteria for each equipment category and to establish a recommended approach for achieving interface compatibility between these subsystem elements and standardized IAS control services. Develop data to support a comparative evaluation of the impact of adapting subsystem equipment to standardized interface characteristics, of using special interface boxes to adapt existing or available subsystem hardware to a standardized IAS interface, and of customizing the IAS interface hardware to achieve compatibility with existing or available subsystem hardware.

(b) For those interface functions which are flight safety critical, evaluate candidate interface techniques to determine the most promising method for incorporation: standard interface, modified for improved protection/isolation, or completely independent of the data bus. Factors for this evaluation include malfunction and damage potential, effect of fault propagation, complexity/dependability delta for integrated versus isolated, and other pertinent factors. Crew control and display requirements will be defined for these items.

WBS Number: 2.3.2.1
Orbiter Tasks (Cont)

(3) Study Approach

(a) Requirements and Methodology. Resolve techniques to be employed in interfacing end equipments (IAS and other) to the central data, command/control, and power distribution elements of the IAS. A prime goal of these studies is to maximize function/equipment commonality, both as the transmission interface and at the end equipment interface.

The baseline concept, of a standardized IAS interface adapted to existing/available end equipments via special interface boxes, will be tested against fault tolerance requirements, checkout requirements, and other considerations which affect interface design. In the case of safety-of-flight functions, isolation from damage and propagated faults will receive special emphasis.

(b) Study Phasing. Identify and categorize interface characteristics of potential equipment. Categorically evaluated requirements in parallel with comparative evaluations of candidate interface techniques. Develop a standardization concept for subsystem interface characteristics, exclusive of safety-of-flight functions. Identify recommended standardized characteristics for data, command, and power characteristics. Develop configuration concepts for any special interface elements, and will consider location, environment, and physical modularization constraints.

Compile recommended concepts, approaches, standards, criteria, and supporting data for technical and program management review.

e. Integrated versus Conventional Avionics

(1) Objectives. Support verification of the integrated IAS approach, and provide estimates of parameters significant to realizeability of an integrated IAS. The study will accomplish a comparative evaluation of the integrated IAS approach versus a discrete approach using conventional avionics elements, emphasizing significant factors such as cost, weight, power, development risk, dependability, etc.

WBS Number: 2.3.2.1
Oribter Tasks (Cont)

(2) Description. Compare the recommended IAS to a conventional modular approach to ensure that the integration process results in equipment which meets necessary requirements with real improvements in cost, risk, and technical performance factors. Data to be developed to support the comparison includes collection of relevant data typical of the modules (e.g., communications, flight controls, computers, timers, IMU's) performing similar functions for existing designs, and criteria and bases (e.g., recurring cost, peak power, maintenance time, development time, volume, etc.) for comparison and analysis.

Cost, size, weight, power, and schedule estimates will be generated for both conventional and integrated concepts, using the proposal baseline configuration. An analysis will be conducted comparing the two configurations, recording all pertinent rationale. This study will provide assurance that the selected design approach most fully satisfies the shuttle program requirements.

(3) Study Approach. Compare the proposal baseline IAS with an equivalent configuration using conventional avionics. A study requirements document will be prepared that will include the following ground rules.

(a) The conventional configuration will use state-of-the-art technology comparable to the baseline IAS configuration.

(b) Subsystems will be configured to redundancy to provide Fail Operational/Fail Operational/Fail Safe.

(c) Performance characteristics of each subsystem will match as nearly as possible the performance provided in the baseline. Inability to match should be noted for trade comparison.

The next step is to define each of the subsystems from conventional hardware for the booster and orbiter. Any significant changes to the baseline ground system resulting from the above definition will be identified.

WBS Number: 2.3.2.1
Orbiter Tasks (Cont)

Data to be evaluated for each subsystem and used in the trade analysis are: Cost, schedule, power, wieght, volume, cooling requirement, crew interface and work load, commonality with similar hardware in other subsystems, redundancy, onboard autonomy, and technology risk.

Company	Function:	Manager:
NR	System Engineering	J. Bates

10. Support IAS in the subsystem analysis, definition, and preliminary design, including trade studies which require mission objectives and requirements; system trade study criteria; measurement and control requirements lists; checkout requirements and timelines; mission and ground and crew operational timelines; ground orbiter and booster interface criteria; orbiter and payload interface criteria; program ferry and ground and flight systems optimization criteria; abort criteria; and information regarding landing, launch, and refurbishment facility.

Company:	Function:	Manager:
NR	Flight Technology	N.F. Witte

11. Provide man and machine interface requirements related to vehicle checkout, flight control, and data management.

    Analyze operator task requirements. Determine crew workload and work and rest cycle.

WBS Number: 2.3.2.1
Orbiter Subcontractor Tasks

Company:	Function:	Manager:
IBM	Integrated Electronics	L.A. Jacowitz

1. IBM will be responsible for the analysis, definition, preliminary design, and ancillary studies of the following elements and functions of the onboard orbiter integrated electronics system: (a) computer configuration and data processing; (b) data, sequencing, and control interfaces with onboard and external equipment; (c) integrated displays and controls, including caution and warning; (d) data and control bus; (e) checkout and fault isolation; and (f) computer software, including language, programming techniques, algorithms, and verification methods.

WBS Number 2.3.2.1
Orbiter Subcontractor Tasks (Cont)

2. IBM will be responsible for the analysis, definition, and ancillary studies of the following ground-based electronic elements and functions that interface with the onboard integrated electronics system.

    a. Data handling
    b. Centralized data processing
    c. Ground-based checkout and support equipment interfaces
    d. Related ground software
    e. Mission control interfaces with DCM
    f. Support hardware and software simulation activities for DCM, ID&C, and COFI performance evaluation.

3. IBM will support NR and GD in the performance of the following IAS trade studies, as described in the prime WBS noted. The support will be in accordance with the technical responsibilities previously described. Similar support will be provided to other Phase B study program efforts in the areas of IBM's responsibilities.

    a. Centralization of functions - WBS 2.3.2.2
    b. Digital interface techniques - WBS 2.3.2.2
    c. Avionics modular design - WBS 2.3.2.1
    d. Power condition, conversion, distribution, and control - WBS 2.3.2.6
    e. Onboard checkout techniques - WBS 2.3.2.8
    f. Configuration and sequencing control - WBS 2.3.2.1
    g. Redundancy techniques - WBS 2.3.2.1
    h. Integrated displays and controls - WBS 2.3.2.4
    i. Integrated sensors and actuators - WBS 2.3.2.1
    j. Integrated versus conventional avionics - WBS 2.3.2.1
    k. Shuttle and ground communication interfaces - WBS 2.3.2.5

Company:	Function:	Manager:
HI	Integrated Electronics	L. Hudson

4. HI will be responsible for the analysis, definition, preliminary design, and auxiliary studies of the following elements and functions of the onboard orbiter and booster integrated electronics system: (a) all inertial sensors, (b) external GN&C sensors (excluding RF equipment), (c) dedicated GN&C electronics, both digital and analog, (d) crew displays and controls associated with GN&C, and (e) checkout and warning associated with GN&C.

WBS Number: 2.3.2.1
Orbiter Subcontractor Tasks (Cont)

5. HI will support NR and GD in the performance of the following IAS trade studies, as described in the WBS listed. The support will be in accordance with the technical responsibilities previously described. Similar support will be provided to other Phase B study program efforts in the areas of HI's responsibility.

    a. Centralization of functions - WBS 2.3.2.2
    b. Digital interface techniques - WBS 2.3.2.2
    c. Avionics modular design - WBS 2.3.2.1
    d. Power condition, conversion, distribution, and control - WBS 2.3.2.6
    e. Onboard checkout techniques - WBS 2.3.2.8
    f. Configuration and sequencing control - WBS 2.3.2.1
    g. Redundancy techniques - WBS 2.3.2.1
    h. Integrated displays and controls - WBS 2.3.2.4
    i. Integrated sensors and actuators - WBS 2.3.2.1
    j. Integrated versus conventional avionics - WBS 2.3.2.1
    k. Shuttle and ground communication interfaces - WBS 2.3.2.5

WBS Number: 3.3.2.1
Booster Tasks

Company:	Function:	Manager:
GD/C	Integrated Avionics	C. Grunsky

1. Support NR in performance of the following IAS system integration tasks, as described in WBS 2.3.2.1, Integration Tasks. Participate in total system integration activities, and assure that items affecting only the booster are accomplished.

    a. Establish the overall integrated avionics system performance requirements on the basis of total program and mission requirements. Define relationships between IAS requirements and program requirements of other vehicle subsystems and of ground operations that affect cost, schedule, safety, and mission effectiveness.

    b. Define the degree of commonality to be achieved in orbiter and booster hardware and software.

    c. Define redundancy policy and candidate methods for IAS.

WBS Number: 3.3.2.1
Booster Tasks (Cont)

d. Coordinate and maintain a dependency matrix and schedule showing major inputs and outputs for tasks within IAS performed by NR, GD, IBM, or HI.

e. Identify areas where research and technology studies are needed to advance the technological areas related to the shuttle program.

f. Submit IAS baseline configuration technical descriptions for inclusion in the System Definition Handbook.

g. Provide technical and management control of study activities affecting the IAS baseline configuration, supporting an internal IAS Configuration Control Board, including representatives of NR, GD, IBM, and HI.

2. Support NR in performance of the following tasks described in WBS 2.3.2.1, Orbiter Tasks.

a. Perform the task of integrating the electromechanical and integrated avionics subsystem (EM/IAS), which includes GN&C, communications, data and control management, onboard checkout, integrated displays and controls, software, and power distribution and controls.

b. Maintain a single top IAS control document that defines a current baseline subsystem configuration.

c. Review all IAS study results for impact on the configuration baseline.

d. Utilize the results of trade studies and analyses to determine the amount of onboard control and automation which is both desirable and feasible.

e. Establish mission impacts, identify critical failure modes (FMEA's), define interfaces, and establish functional characteristics and functional block diagrams of concepts for the overall IAS.

f. Accomplishment of trade studies for avionics modular design, configuration and sequencing control, redundancy techniques, integrated sensors and actuators, and integrated versus conventional avionics. Specific emphasis will be placed on any booster unique tasks/functions related to these trade studies.

WBS Number: 3.3.2.1
Booster Tasks (Cont)

g. Establish preliminary performance characteristics. Device equipment interface parameters including weight, power, volume, form, environment control requirements, and signal characteristics, including type, level, timing, etc. Establish subsystem and software cost and schedule impacts and support research and technology requirements. Prepare subsystem and software performance and interface specifications to include technical data for preliminary specification and for ICD's.

h. Provide safety data to support a system safety analysis for all aspects of the EM/IAS, including prelaunch; launch, abort and recovery; range safety, in-orbit safety, escape and rescue, and recovery missions. Identify and classify potential and inherent hazards. Conduct safety analysis. Provide detailed description of identified hazards, and prepare hazard analysis sheet. Define safety considerations. Include identification of safety assumptions, documentation of safety rationale, evaluation of influence of assumptions, and identification and documentation of residual hazards.

i. Provide inputs in support of failure mode and effects analysis (FMEA), including requested data in columns 1, 5, 6, and 10 on the FMEA form for each major function in the applicable subsystem.

3. Perform integration functions which include technical and administrative liaison between GD and associated team members and the various agencies of the customer and support to GD and NR management in preparation of program documentation and the preparation and presentation of program data at briefings, meetings, intercenter conferences, etc.

SPACE SHUTTLE PHASE B
TASK DESCRIPTIONS

WBS TITLE: DATA AND CONTROL MANAGEMENT (DCM)

WBS Number: 2.3.2.2
Integration Tasks

Company:	Function:	Manager:
NR	Integrated Avionics	G. C. Anderson

1. Evaluate and approve results of IBM DCM design and trade studies so that a technical position on DCM baseline may be recommended.

2. Prepare technical status briefings on DCM for NR management and for NASA throughout the Phase B study.

3. Provide technical coordination between GD/C, IBM, HI, and NR ICD's related to DCM.

4. Provide technical coordination with configuration control boards on items related to DCM baseline.

5. Provide technical coordination with other engineering groups to assure timely delivery of data required for DCM studies. Submit and control data forwarded to IBM.

6. Provide technical coordination with other engineering groups to assure the derivation of data (i. e., subsystem performance requirements) in proper format from DCM studies to satisfy their needs.

7. Study and evaluate design objectives of DCM studies so that scope of DCM studies as performed properly reflects influence on vehicle and subsystem design.

8. Provide safety data to support a system safety analysis for all aspects of the EM/IAS:

   a. Identify and document use of materials that are not on the approved materials list.

   b. Identify and document concepts, equipments, and procedures wherein malfunctions may cause hazardous conditions.

WBS Number: 2.3.2.2
Integration Tasks (Cont)

9. Provide inputs in support of failure mode effects analysis (FMEA):

   a. Identify and document equipment with high failure-rate histories.

   b. Identify all single-point failure points and describe modes during which a malfunction could cause a loss of a critical function.

10. Provide technical support in the compilation and analysis of the orbiter vehicle master measurement and control requirements documentation.

WBS Number: 2.3.2.2
Orbiter Tasks

Company:	Function:	Manager:
NR	Integrated Avionics	G. C. Anderson

1. Perform the centralization of functions study. Study to include:

   a. Analyze orbiter vehicle processing, control, and data management requirements.

   b. Define study evaluation criteria.

   c. Establish critical parameters and functions.

   d. Identify potential concepts, technologies, and procedures.

   e. Review booster-unique requirements and, with support of GD/C, establish deltas and/or conceptual modifications, as appropriate.

   f. Evaluate each selected concept, assembly, and procedure in relation to evaluation criteria and performance requirements.

   g. Establish optimum subsystem configuration and identify orbiter/booster deltas.

   h. Prepare interim and final study documentation as well as supporting data.

WBS Number: 2.3.2.2
Orbiter Tasks (Cont)

2. Perform the digital interfaces technical study. Study to include:

   a. Analyze orbiter vehicle data communication requirement.

   b. Review vehicle master measurements lists and identify number and type of measurement data rates, accuracies, origin, utilization points, etc.

   c. Establish peak and average data rates by selected mission phases to size data traffic limits.

   d. Define study evaluation criteria.

   e. Review orbiter/booster-unique operational, location, and hardware requirements.

   f. Identify potential concepts, technology, and procedures.

   g. Evaluate each selected concept, assembly, and procedure in relation to evaluation criterion and program requirements.

   h. Establish optimum configuration and identify orbiter/booster deltas.

   i. Prepare study documentation and supporting data.

During all phases of this study, specific evaluation of EMI susceptibility as well as EMI alleviation techniques will be made.

3. Define the functions and requirements of the data and control management subsystem. Tasks to include:

   a. Establish mission impacts.

   b. Define hardware interfaces.

   c. Identify and define functional characteristics.

   d. Prepare functional block diagrams.

WBS Number: 2.3.2.2
Orbiter Tasks (Cont)

4. Establish preliminary performance and design characteristics:

   a. Define equipment concept, power, volume, and form factor.

   b. Establish signal characteristics (e.g., type, level, timing, etc.). When timing accuracy is specified, consideration will be given to required vehicle autonomy and the use of timing equipment that does not require updating.

   c. Establish equipment/subsystem cost and schedule impacts, risks, etc.

5. Support the program by identifying critical research and technology requirements.

6. Define major interface between IAS and ground system, e.g., data flow, ground commands, and facility requirements.

7. Evaluate impact of abort-imposed requirements.

8. Evaluate GN&C operational requirement impact on data management subsystem.

9. Support the preparation of subsystem interface schematics for the preliminary design definition of orbiter/launch hardware components.

10. Perform a tradeoff study to determine the practicality of programming the operating power to signal conditioning, sensors, and other devices.

11. Collect preliminary parametric data to support digital interface techniques and centralization of functions trade studies.

12. Evaluate alternate methods of providing computer bulk memory using 1973-75 technology.

13. Evaluate use of advanced technology beyond 1972 time period to increase payload capability. Areas of investigation will include: (a) reduction in hardware size and weight; (b) reduction in quantity of hardware components; (c) improved equipment and system accuracy, with resultant increase in vehicle performance and payload. Prepare report(s) on findings and support briefings presenting results.

WBS Number: 2.3.2.2
Orbiter Tasks (Cont)

14. Support the evaluation of radiation survivability data for candidate computer and data bus equipment for both orbiter and booster. Recommend requirements and/or concepts for utilization in the space shuttle data management subsystem.

WBS Number: 2.3.2.2
Orbiter Subcontractor Tasks

Company:	Function:	Manager:
IBM	Integrated Avionics	L. A. Jacowitz

1. Support NR in the evaluation of other subcontractor-derived data that impact upon the data management subsystem, such as may be required for guidance and navigation computation.

2. Provide support analysis where configuration selection may impose a major impact upon the data management subsystem location, operating, conditions, environments and procedures, or physical parameters such as weights, power and volume/form, or may impose severe calibration and/or maintenance requirements.

3. Perform subsystem configuration definition and redundancy studies, identify and evaluate alternative hardware and software approaches, and perform tradeoff studies to select desired approach. Identify new hardware and software. Define modifications or additions to existing flight hardware and ground facilities and equipment.

4. Define research and technology programs and areas to support timely development of critical equipment.

5. Provide design support to NR for mockup, simulator/evaluator activities.

6. Provide support in the analysis of crew operational time lines and in the analysis of crew operations for rendezvous and docking.

7. Provide support to the derivation of a development test philosophy by analysis of costs, timing, tests, and effectiveness within guidelines established by NR.

WBS Number: 2.3.2.2
Orbiter Subcontractor Tasks (Cont)

8. Identify potential system deltas and establish programmatic impact of non-autonomous operation.

9. Support the space shuttle system safety study by evaluation of the data management subsystem during prelaunch operations, launch including abort and recovery, range safety provisions, escape and rescue in-orbit, and recovery implications.

10. Support NR as required to prepare and present appropriate data at formal and informal briefings, presentations, etc., and assist NR in the preparation of formal report documents.

WBS Number: 3.3.2.2
Booster Tasks

Company:	Function:	Manager:
GD/C	Integrated Avionics	C. Grunsky

1. Provide booster-unique data and assist NR in providing booster/orbiter common data to support the system safety analysis.

2. Provide booster-unique data and assist NR in providing booster/orbiter common data to support a failure mode effects analysis (FMEA).

3. Assist NR in the development of the booster/orbiter common DCM subsystem predesign data.

4. Determine booster-peculiar requirements and assist NR in determining booster/orbiter common requirements for the DCM subsystem.

5. Assist NR by analyzing orbiter-peculiar requirements and predesign data to assure maximum commonality between orbiter and booster DCM subsystems.

6. Support NR in the integration functions which include technical and administrative liaison between associated team members and the various agencies of the customer and assist NR in the preparation of program documentation and preparation and presentation of program data at briefings, meetings, intercenter conferences, etc.

WBS Number: 3.3.2.2
Booster Tasks (Cont)

7. Support NR in the evaluation of existing computer development simulation programs.

8. Provide support to the centralization of functions as defined in WBS 2.3.2.2, Orbiter Tasks, Item 1. In addition, booster-unique requirements will be identified.

9. Provide technical direction for the digital interfaces techniques trade study described in WBS 2.3.2.2, Orbiter Tasks, Item 2. In addition, booster-unique requirements will be identified.

SPACE SHUTTLE PHASE B
TASK DESCRIPTIONS

WBS TITLE: GUIDANCE, NAVIGATION, AND CONTROL (GN&C)

WBS Number: 2.3.2.3
Integration Tasks

Company:	Function:	Manager:
NR	Integrated Avionics	G. C. Anderson

1. Evaluate and approve results of GN&C HI design and trade studies so that a technical position on GN&C baseline may be recommended.

2. Prepare technical status briefings on GN&C for NR management and for NASA throughout the Phase B study.

3. Provide technical coordination between GD/C, IBM, HI, and NR ICD's related to GN&C.

4. Provide technical coordination with configuration control boards on items related to GN&C baseline.

5. Provide technical coordination with other engineering groups to assure timely delivery of data required for GN&C studies. Submit and control data forwarded to Honeywell, Inc.

6. Provide technical coordination with other engineering groups to assure the derivation of data (i. e., subsystem performance requirements) in proper format from GN&C studies to satisfy their needs.

7. Study and evaluate design objectives of GN&C studies so that scope of GN&C studies as performed properly reflects influence on vehicle and subsystem design.

WBS Number: 2.3.2.3
Orbiter Tasks

Company:	Function:	Manager:
NR	Integrated Avionics	G. C. Anderson

1. Work with HI in planning and scheduling of studies.

2. Provide analysis of study results.

3. Provide spot checks of HI studies to verify results.

4. Provide and update top-level GN&C document which outlines scope of studies and primary study objectives.

5. Monitor HI progress on studies against study objectives and schedules.

6. Provide technical direction and control of HI to assure that study objectives are properly understood, that analysis techniques used are optimum, and that work is performed in a timely manner compatible with vehicle design schedules.

WBS Number: 2.3.2.3
Orbiter Subcontractor Tasks

Company:	Function:	Manager:
HI	Integrated Avionics	L. Hudson

1. The GN&C subcontractor for shuttle Phase B activity, Honeywell, Inc. (HI), will perform the tasks set forth below in support of NR/GD/C under overall NR integration and technical direction efforts.

2. For major trade studies, HI will conduct and/or lend support to NR/GD/C as specified in each of the two shuttle configurations: straightwing and delta (high cross range) orbiters in conjunction with the GD/C booster. The key parameters to be considered in making the trades are as follows.

WBS Number: 2.3.2.3
Orbiter Subcontractor Tasks (Cont)

Tradeoff Required and Purpose	Key Parameters
Gimballed vs. strapped-down inertial measurement unit (IMU), sensor selection Purpose: To select the IMU configuration best suited for the shuttle requirements.	All-attitude capability Computer memory and speed Commonality of sensor Size Weight Turnaround time Cost Ease of redundancy implementation Test and maintenance impact Performance (alignment, vehicle maximum rates, calibration) Reliability Design risk Compatibility with other equipment Experience Sensors (accuracy and power)
Nonresident/central vs. resident/dedicated GN&C computer Purpose: To support NR as required by providing data listed under key parameters in the selection of the GN&C computer approach which minimizes unusable computer capability in DCM while assuring proper data interface with respect to rest of system.	ICD simplicity Mode-switching simplicity Size Weight Power Cost Reliability/redundancy Commonality Speed/data rate/word length Fault isolation and checkout Software complexity
Degree of GN&C autonomy Purpose: To achieve cost-effective allocation of GN&C initialization/targeting functions between on-board and ground-based equipment/personnel.	Delta cost and weight Number and frequency of special missions (i.e., non-baseline) Amount of ground OPS during missions (special and baseline)

WBS Number: 2.3.2.3
Orbiter Subcontractor Tasks (Cont)

Tradeoff Required and Purpose	Key Parameters
	Kind and extent of ground-to-vehicle interface and GSE Type and extent of pilot/GN&C interface Development risk
Participate in overall shuttle study by providing an evaluation of the degree of pilot routine participation in baseline GN&C functions Purpose: To allocate functions between automatic and manual modes of control while providing adequate pilot control over vehicle and mission.	Accuracy achievable Cost differential Crew workload Degree of checkoug and fault-isolation simplification Status monitoring of other systems Complexity level Degree of design feasibility Safety level differential Manned vs. unmanned booster Degree of hardware commonality between booster/orbiter (hand controllers, etc.) Pilot opinion
Support NR/GD/C as required: load relief during boost vs. trajectory accuracy. Purpose: To determine the type of load relief required.	Complexity of control Design risk Reliability/redundancy Effects of trajectory deviations on deliverable payload
Support NR as required: automatic vs. manual docking/rendezvous control Purpose: To choose a cost-effective concept for accomplishing docking/rendezvous within shuttle requirements.	Performance difference Complexity of sensor array Cost Impact stresses Weight Reliability/redundancy Manual override equipment

WBS Number: 2.3.2.3
Orbiter Subcontractor Tasks (Cont)

Tradeoff Required and Purpose	Key Parameters
	Expendables/energy management Crew workload/skills Design/development risk/ state of art Navigation errors
Automatic landing system definition and implementation: ILS vs. automatic GCA Purpose: To determine clearly the penalties of having an automatic landing capability; to implement decision for automatic or manual landing; and to select optimum system for shuttle.	FAA compatibility problem Cost impact Crew workload Reliability/redundancy Reusability/turnaround Commonality Status monitoring functions Amount of GSE vs. ASE ILS-type Cat. II system Automatic GCA (SPN-42)-type Cat. II system Accuracy Size Weight Input power
Star tracker/horizon sensor vs. other optical sensors (e.g., manual vs. automatic sextant for GN&C initialization and calibration Purpose: To define the need and requirements for optical aids used for in-orbit platform initialization and navigation.	Computer memory impact Cost Size Weight Reliability/redundancy Baseline mission need to power down/up Prelaunch optics requirements Installation impact/airframe integration requirements Crew workload Optical ranging use for rendezvous

WBS Number: 2.3.2.3
Orbiter Subcontractor Tasks (Cont)

Tradeoff Required and Purpose	Key Parameters
Modular concept Purpose: To determine the extent of modularization and functional groupings in the GN&C system based on NR/GD/C electronics guidelines.	Test and maintenance impact Impact on packaging, mounting, cooling, interconnections, circuit design, and parts selection
Reliability/redundancy implementation Purpose: To determine appropriate level and combinations of levels of GN&C redundancy to meet the fail-OP/fail-OP/fail-safe requirement without undue penalties.	Cost Size Weight Power Reliability Commonality Maintainability Fault isolation and checkout system Performance
Automatic inertial vs. ground navigation Purpose: To establish allocation and need to use nav-aids for reentry.	FAA compatibility Accuracy Performance Reliability Complexity of sensor array Commonality of rendezvous/auto-land and nav-aid sensors
Adaptive control vs. gain scheduling or fixed-gain for boost, entry, and aerodynamic flight Purpose: To determine the degree of sophistication required.	Computer storage and computation rate Sampling rate Handling qualities Excitation and damping of structural modes Cost differential Complexity Design risk Reliability/redundancy Sensors required Structural loads

WBS Number: 2.3.2.3
Orbiter Subcontractor Tasks (Cont)

Tradeoff Required and Purpose	Key Parameters
Support NR as required: powered vs. unpowered landing requirements Purpose: To determine the feasibility of guiding the orbiter vehicle through approach and landing without benefit of jet engines for a powered approach.	GN&C cost and weight differential Design risk Reliability/redundancy Landing footprint vs. entry guidance dispersions
Air-data vs. no air-data sensors Purpose: To assess feasibility of performing shuttle missions without air data.	Weight Safety FAA certification Performance
GN&C abort philosophy and implementation Purpose: To support NR/GD/C as required to choose between alternative GN&C abort philosophies and means of implementing them.	Abort trajectories Return footprint/sites Equations/solutions Abort regimes Maximum control moment available and source Amount and degree of hardware/software reconfiguration necessary and allowable for aborts and targeting Landing/go-around decision point Computer memory impact

3. HI will provide the results of analyses and support NR/GD/C with data to select and verify conceptual design and to assure an effective crew interface with the GN&C system for all flight phases.

   a. Navigation

      (1) Requirements for prelaunch alignments and calibration of inertial instruments

WBS Number: 2.3.2.3
Orbiter Subcontractor Tasks (Cont)

(2) Checkout requirements

(3) Pointing-accuracy requirements

(4) Inertial reference system alignment techniques and achievable accuracies on orbit

(5) State-vector-updates performance requirements for the rendezvous

(6) De-boost navigation including abort from orbit, error analysis, RCS de-boost, and de-orbit engine de-boost based upon NR trajectories

b. Guidance

(1) Prelaunch targeting equations and initialization software and/or hardware

(2) Checkout requirements

(3) Ascent guidance law definition and guidance error analysis - targeting equation definition

(4) Rendezvous guidance, error analyses

(5) Reentry guidance law sensitivities based upon NR-supplied heating and g corridors

(6) Abort guidance and targeting

(7) Engine(s)-out guidance

(8) De-boost guidance and targeting including abort from orbit, error analysis, RCS de-boost, and de-orbit engine de-boost based upon NR/GD/C trajectories

c. Flight control system

(1) Checkout requirements

(2) Ascent attitude and load relief control system design based upon NR bending and sloshing models

WBS Number: 2.3.2.3
Orbiter Subcontractor Tasks (Cont)

(3) Separation control system based upon NR-supplied separation dynamics analysis

(4) Main propulsion system actuator dynamic performance requirements envelopes

(5) Ascent abort control requirements

(6) Ascent engine(s)-out control performance

(7) On-orbit attitude time line from reference mission

(8) On-orbit and reentry limit cycle operation analyses: deadband requirements, control moment duty cycles

(9) Closed-loop attitude control during RCS ΔV and normal ΔV operations

(10) Approach and docking FCS, manual and automatic

(11) Pitchdown maneuver definition based on NR-supplied initial conditions

(12) Automatic landing gate acquisition technique including the interface with landing and navigation aids

(13) Aerodynamic surface and jet engine throttle actuator dynamic analyses and performance requirements envelope

(14) ACPS moments needed for reentry, separation, and on-orbit

(15) Total control moment impulse and number of RCS engine starts during reentry.

(16) Handling qualities during reentry, landing, and ferry with augmented control based on NR aerodynamic and control surface data

(17) Integration of flight control system with landing aids

(18) 3σ touchdown dispersions

WBS Number: 2.3.2.3
Orbiter Subcontractor Tasks (Cont)

(19) Landing sink rate, crosswind operating envelope defined

(20) Control requirements on landing gear design, nosewheel actuator dynamic authority

(21) Accuracy requirements for roll-out aids

(22) Gust alleviation and bending mode suppression system analyses during ferry

d. Displays and controls

(1) Provide GN&C functional requirements for crew command and monitoring including mission plans and schedule analyses.

(2) Provide interface requirements and constraints of other subsystems interfacing with D&C for GN&C.

(3) Assist NR/GD/C in performing D&C commonality analyses/ tradeoffs at subsystem level.

(4) Provide D&C parameters and performance required for GN&C.

(5) Provide any flight control requirements for unique D&C (i.e., hand controllers, electromechanical backup display devices).

(6) Provide any direct interfaces between GN&C and D&C.

(7) Provide the best method of system mechanization for maximum utilization of system capability for mode versus function switching. Key parameters to be considered are crew workload, ease of redundancy implementation, test and maintenance impact, turnaround time, and size.

4. Conceptual design

a. Common design

Provide the following for the GN&C system:

(1) A block diagram of the entire G&N subsystem showing G&N inputs, outputs, and interfaces with other equipment

WBS Number: 2.3.2.3
Orbiter Subcontractor Tasks (Cont)

(2) A description of major elements, dimensions, weights, volume, power consumption, and any unique installation features of requirements

(3) Functions for uplink/downlink transmission

(4) Subsystem description to support the NR/GD/C system specification

(5) All interface and performance requirements with other subsystems

(6) Functional block diagram of the computer showing input/output, memory, and other functional elements of the computer and its interface with the major system elements

(7) Preliminary description of major elements including size, weight, power, volume, and required instruction repertoire

(8) Description and analysis of redundancy design to accomplish mission reliability requirements

(9) Block diagram of the FCS with inputs and outputs

(10) Identification of state-of-the-art advancements required to complete requirements for shuttle GN&C

b. Guidance and navigation subsystem

Provide the following for the guidance and navigation subsystem:

(1) An integrated all collection of all basic guidance equations and targeting equations

(2) Any unique state-vector integration methods (e.g., conic solutions, non-real-time integrations)

(3) An integrated collection of GN&C sensor design requirements and results of error analysis

(4) Flow logic for platform alignments and on-board navigation

(5) IMU algorithm

WBS Number: 2.3.2.3
Orbiter Subcontractor Tasks (Cont)

c. Flight control design

Provide the following for the flight control subsystem:

(1) I/O, memory size, erasable load, etc., and other characteristics together with any unique installation features or requirements

(2) Flow chart description of the computer routines for the flight control computer for all mission phases

(3) Document interface data and transfer functions for jet engine automatic thrust control

d. Displays and controls

The conceptual design for the displays and controls to provide the crew interface with the GN&C subsystem shall be accomplished by the following:

(1) Evaluate candidate GN&C display/control parameters and recommend functional groupings. Recommend symbology and format appropriate to functional groupings.

(2) Accomplish and document configuration and performance definition for dedicated GN&C D&C, including integration with interfacing subsystems.

(3) Provide design support to mockup activities. Monitor man/machine interface evaluation and recommend necessary corrections to D&C design.

5. Support and checkout requirements

Provide design requirements for ground and in-flight checkout, monitoring and test of the G&N, FCS, computer, and D&C subsystems. The design requirements shall be primarily based on cost-effectiveness considerations to determine the division of ground and on-board checkout tasks for the GN&C subsystems. Ground versus on-board checkout tradeoff study data developed by NR will be supplied.

WBS Number: 2.3.2.3
Orbiter Subcontractor Tasks (Cont)

a. The scope of this task includes the following:

(1) Provide requirements for on-board performance monitoring, failure detection, redundancy management and, where practical, detection of impending failures of the GN&C subsystems.

(2) Provide requirements for ground turnaround and prelaunch checkout of the GN&C subsystem.

b. As a result of this task, HI shall provide to NR/GD/C the following data:

(1) Functional block diagrams illustrating GN&C checkout hardware including other vehicle subsystem interfaces

(2) Description of major GN&C subsystem support equipment elements, dimensions, volume, weight, power consumption, and any unique installation features or requirements

(3) Description of crew checkout functions throughout the baseline mission. Description of ground crew checkout functions during turnaround GN&C checkout operations

(4) Checkout and calibration GN&C computer program requirements including fault-isolation logic

(5) Subsystem description to support NR/GD/C system specification

6. Provide a reliability and quality assessment of the preliminary design concepts and preliminary manufacturing approaches for the space shuttle GN&C system. This effort shall place emphasis on optimizing the approach to systems design redundancy and maintainability and on reviewing failure mode effects analyses. HI shall recommend reliability criteria for the design of the space shuttle GN&C.

7. Provide a failure mode effects analysis to determine the most probable failure modes and to identify and eliminate any single-point failures and assume compliance to fail-OP/OP-safe requirements.

8. Provide support to NR/GD/C in developing electromagnetic interference control criteria.

WBS Number: 2.3.2.3
Orbiter Subcontractor Tasks (Cont)

9. Provide support to NR/GD/C gross hazards analysis including the results of any safety considerations evaluated during the above studies.

10. Develop a requirements baseline document for the shuttle GN&C system. The data analysis is to be based on mission data and other requirements data supplied by NR/GD/C. The task is limited to derivation GN&C requirements from shuttle system and vehicle performance and operational characteristics supplied by NR/GD/C.

11. Submit support data to NR/GD/C for the below-listed preliminary plans and specifications for conducting the Phase B (study), Phase C (design), and Phase D (development/operations) portions of the Space Shuttle Program.

    a. Program Management Plan

    b. Engineering/Development Plan

    c. Operations Plan

    d. Facilities Utilization and Manufacturing Plan

    e. Test Plan

    f. Logistics and Maintenance Plan

    g. Project Cost and Schedule Estimates Plan

12. Perform a study to define the impact of specified radiation levels on the GN&C electronics. Study to include, as a minimum, estimates of cost, schedule, risk, weight, power, and volume deltas resulting from "hardening" the electronics. In addition, the effect of the radiation upon nonhardened electronics shall be estimated.

WBS Number: 3.3.2.3
Booster Tasks

Company:	Function:	Manager:
GD	Integrated Avionics	C. Grunsky

1. Provide direction to HI and evaluate HI work results and proposed solutions in terms of effects on total system operations and time required, effects on autonomy, lift-off weight, and ΔV and fuel increments for rendezvous. These efforts will be directed in the following areas:

    a. Prelaunch targeting equations and initialization software and/or hardware

        (1) Provide guidance on scope of task to HI.

        (2) Review and evaluate HI-proposed approaches/techniques to accomplish the targeting and initialization operations.

        (3) Provide technical direction to HI on techniques/procedures for on-board targeting computations.

    b. Ascent guidance law definition; guidance error analysis

        (1) Review/evaluate the HI-proposed guidance law approach and the supporting data and analysis.

        (2) Review error analysis and results for adequacy; provide vehicle trajectories for the error analyses.

    c. Abort guidance and targeting

        (1) Provide HI with definitions of conditions that will cause abort; describe the remaining vehicle capabilities. These are inputs to the abort guidance study.

        (2) Review proposed approach for effects on system operations.

    d. Engine(s)-out guidance

        (1) Review/evaluate proposed guidance approach in case one or more engines go out; review/evaluate supporting data and analysis.

WBS Number: 3.3.2.3
Booster Tasks (Cont)

e. Targeting - booster and orbiter to injection into orbit

(1) Provide guidelines to HI.

(2) Review proposed targeting software and procedures for possible improvements.

(3) Evaluate proposed ground/on-board division of targeting computations in terms of effects on countdown operations and supporting equipment.

2. Review, evaluate, and provide direction for HI navigation studies.

a. Requirements for prelaunch alignment and calibration of inertial sensors

Review and evaluate data and analysis used by HI to derive requirements. Study proposed procedures/operations for accomplishing calibration and alignment to determine effects on prelaunch operations both on-board and in the ground facility.

b. IMU alignment determination

Vertical: Review HI approach for adequacy, accuracy, and efficiency.

Azimuth: Review method and procedure for possible improvements.

Evaluate the HI-proposed techniques and provide technical direction to guarantee compatibility with operations and supporting equipment of the integrated system.

c. Commonality of booster/orbiter navigation operations

Maintain coordination with NR and HI to assure maximum practical common equipment and operations for booster and orbiter systems.

WBS Number: 3.3.2.3
Booster Tasks (Cont)

3. Review and evaluate HI studies, results, and conclusions.

   a. Integrated software package

      Review/evaluate proposed solutions and approaches to the problem of achieving an integrated software package consisting of all logical and computation functions of the guidance and navigation subsystems.

   b. Unique software methods

      Review such proposed approaches and evaluate in terms of effects on and significance in the subsystem operations, accuracy, reliability, and/or other factors.

   c. GN&C design and accuracy requirements - tradeoff with rendezvous, reentry

      Review to ascertain that these requirements are compatible with shuttle operations and mission requirements.

   d. IMU alignment and on-board navigation

      Review/evaluate proposed alignment approaches and determine effects on vehicle operations, injection accuracies, computations, and equipment required.

   e. IMU algorithm

      Review supporting analysis and data on the selected algorithm for validity or reasonableness of conclusions.

   f. Commonality of booster/orbiter systems design

      Review proposed designs and assist NR to assure maximum practical commonality.

4. Provide technical direction to HI and assist in performing analyses necessary to verify that the flight control system assures adequate safety of flight and desirable handling qualities throughout the nominal and abort flight regimes. Verify that sufficient redundancy was implemented to satisfy the fail-operational/fail-safe ground rule

for electrical systems. The following Honeywell tasks relating to the booster FCS will be coordinated under the overall GN&C technical direction to HI by NR:

a. Ascent attitude and load relief

b. Separation control system

c. Main propulsion system actuator dynamic performance requirements

d. Ascent abort control requirements

e. Booster performance with engine out during ascent

f. Transition from high to low angle of attack

g. Handling qualities during booster entry, ferry, and landing

h. Integration of FCS with landing aids

i. Gust alleviation and bending mode suppression system analysis during ferry

j. FCS gyro and accelerometer specifications

5. Assist NR in the monitoring of Honeywell, Inc., trade studies concerned with the booster and the combined booster/orbiter vehicle during launch, load relief, and abort. These trade studies are load relief during boost vs. trajectory accuracy; air-data sensors vs. no air-data sensors; and GN&C abort philosophy and implementation.

6. Assist NR in preparing a data package for HI's use in its guidance and navigation analyses.

SPACE SHUTTLE PHASE B
TASK DESCRIPTIONS

WBS TITLE: CREW STATION/DISPLAYS AND CONTROLS

WBS Number: 2.3.2.4
Integration Tasks

Company:	Function:	Manager:
NR	Integrated Avionics	G. C. Anderson

1. Coordinate Phase B tasks between NR, GD/C, and subcontractors to assure continuity, visibility, adequacy, and uniformity of effort; coverage of program requirements; and commonality of hardware between vehicles, so that the booster will have crew station displays and control basically identical to the orbiter except for differences resulting from unique booster requirements.

2. Direct and monitor IBM and HI activities related to integration of crew station functions with other IAS and vehicle functions. Evaluate and approve subcontractor analysis, definition, and design results.

3. Coordinate requirements and data flow between subcontractors and other engineering groups.

4. Support production of system- and project-level design documentation, including inputs to specifications, data manuals, ICD's, etc.

5. Support integration studies in areas affecting or interfacing with crew station/displays and controls such as physical modularization, redundancy, checkout methodology, optimum employment of the flight crew, etc.

6. Provide technical status information and support subsystem, system, and project reviews by NR management and NASA. Accomplish direct technical coordination with designated NASA representatives as required.

WBS Number: 2.3.2.4
Orbiter Tasks

Company:	Function	Manager:
NR	Integrated Avionics	G. C. Anderson

1. Identify flight crew decision/action requirements and constraints; define flight crew command and monitoring interface functions.

2. Define display/control and caution/warning interfaces with vehicle subsystems.

3. Develop and update a whole-panel configuration concept. Evaluate candidate display/control parameters, select parameters, and develop functional groupings. Select symbology, formats, and nomenclature. Define principal levels of information for displayed parameters and principal level of command for manual controls consistent with crew workload and hardware complexity considerations. Assist in determining which control modes and functions are to be primarily manual and which primarily automatic with manual backup. Participate in determining the extent of flight-mode automation, including aborts, docking, landing, etc.

4. Provide technical direction, control, and integration of subcontractor efforts in subsystem-level analysis, definition, and design, including:

   a. IBM analysis, definition, and design for the integrated displays and controls (ID&C) subsystem. IBM tasks relative to ID&C are defined under the Subcontractor section of this WBS.

   b. HI analysis and definition efforts for GN&C-unique displays and controls. HI tasks relative to these displays and controls are defined under the Subcontractor section of WBS 2.3.2.3.

5. Establish appropriate design standards, equipment performance, and integration criteria for crew displays and controls and for caution/warning and lighting equipment.

6. Plan, conduct, and coordinate subcontractor support to an integrated displays and controls trade study. This study will explore the most effective degree of display/control integration, considering crew decision and action requirements, human engineering and system effectiveness

WBS Number: 2.3.2.4
Orbiter Tasks (Cont)

criteria, mission flexibility/growth, and available technology. Early definition of the most promising operational methods and techniques for display/control integration will be made. Specific objectives of the study are:

a. To determine the scope, levels, and types of data and command/control access which the flight crew should have in order to manage the mission, vehicle, and subsystems in the most effective manner.

b. To evaluate promising display/control concepts and define the recommended extent and technique of integration to provide best interface effectiveness.

c. To assess the technological feasibility of replacing conventional electromechanical display/control elements with all-electronic elements compatible with a computer interface.

d. Options and major issues.

Issues	Options
Display/control organization	Integrated (multifunctional), dedicated (single-function), mixed
Display method	Graphic, pictorial, alphanumeric, other
Level of manual command	Mode, function, other
Display technology	CRT, electro-optical, plasma, solid-state
Control technology	Conventional, electronic/noncontact
Level of information displayed	System, subsystem, component, other

WBS Number: 2.3.2.4
Orbiter Tasks (Cont)

e. Trade study subtasks.

(1) Prepare study plan, direct and coordinate study activities with affected groups and subcontractors.

(2) Develop and provide D&C and C/W functional requirements, crew interface criteria, vehicle/interface constraints, preliminary whole-panel concept/approach, and baseline update to participating groups and subcontractors.

(3) Develop crew interface integration requirements and constraints. Define cockpit practices to be used as basis for integration studies. Define a whole-panel integration approach. Provide data to participating groups and subcontractors.

(4) Direct and monitor IBM study efforts in support of display integration trades, controls integration trades, and display/control technology trade.

(5) Evaluate alternate concepts and practices.

7. Perform layout studies and execute a preliminary crew station design layout. Produce preliminary drawings depicting arrangement of display/control hardware relative to the crew station.

8. Provide direct design support to soft mockup and simulator activities for man/machine interface evaluation. Monitor and support evaluation activity. Define and implement configuration/arrangement corrections.

Company:	Function:	Manager:
NR	Flight Technology	N. F. Witte

9. Provide man/machine interface requirements related to vehicle checkout, flight control, and data management. Output is required in support of basic display/control tasks, trade studies, and other functional activities.

10. Analyze operator tasks requirements. Determine crew workload and work/rest cycle.

Evaluate the results of the following Company-sponsored efforts and provide the data as required to support NR integration and orbiter tasks.

WBS Number: 2.3.2.4
Orbiter Tasks (Cont)

a. Develop crew operational requirements, constraints, and capabilities on typical shuttle vehicle flight phases.

b. Develop human factors component evaluation checklist based on display-control requirements.

c. Develop preliminary flight crew operational procedures for total mission operations. Task, time-line, and link-analysis techniques will be applied as required.

d. Conduct human factors evaluation on the suitability of controls and display components under advanced development.

e. Develop and define preliminary crew information and task requirements to perform all crew operational functions.

WBS Number: 2.3.2.4
Orbiter Subcontractor Tasks

Company	Function	Manager:
IBM	Integrated Avionics	L. A. Jacowitz

1. Analyze NR-furnished mission, crew, and operations requirements to determine effect on ID&C.

2. Evaluate promising display/control techniques as a basis for ID&C development.

3. Support configuration analysis and provide physical data related to size, weight, power, volume, location, and installation constraints for ID&C equipment.

4. Participate in development and support analysis of flight crew operational time lines task requirements.

5. Accomplish ID&C configuration definition; identify and evaluate alternate approaches. Perform trade studies to select recommended approach. ID&C is defined as the aggregate of the multipurpose displays and multi-functional crew controls whose vehicle interface is through the DCM (WBS 2.3.2.2). This includes caution and warning.

WBS Number: 2.3.2.4
Orbiter Subcontractor Tasks (Cont)

6. Evaluate candidate display/control and caution/warning parameters and recommend functional groupings, symbology, and format appropriate to equipment organization.

7. Perform configuration logic studies to define redundancy and manual backup requirements. Support subsystem failure mode effects analysis (FMEA) effort.

8. Accomplish ID&C preliminary design; provide design data and equipment performance specifications.

9. Define required research or technology effort to development critical equipment.

10. Provide design support to NR for soft mockup and simulator/evaluator activities.

11. Participate in the integrated displays and controls trade study. Under NR direction, perform tradeoffs between the various options for (a) display/control organization, (b) display method, (c) level of manual command, and (d) display and control technology. Submit recommendations for NR review. Provide documentation of tradeoff process and supporting data.

12. Accomplish necessary integration between ID&C, the data management function, and other interfacing functions within IBM's area of subsystem design responsibility.

WBS Number: 3.3.2.4
Booster Tasks

Company	Function	Manager:
GD/C	Integrated Avionics	C. Grunsky

1. Identify and define booster-peculiar display/control functions and requirements (crew functions, information requirements, subsystem interfaces, study technology data, etc.). Documented inputs will be maintained and updated in a crew systems data bank and provided to numerous trade and design study activities.

WBS Number: 3.3.2.4
Booster Tasks (Cont)

2. Perform a preliminary crew function analysis leading to a definition of the man/machine functional relationships within the IAS. Report documentation includes:

    a. Functional analysis description and approach

    b. Data-bank punch-card format

    c. Standard abbreviations list

    d. Standard task action verb list

    e. Crew functional requirements/constraints

    f. Preliminary mission phase/crew function list

3. Support the integrated displays and controls trade study for the following tasks:

    a. Provide inputs for the preparation of study plan, technical direction, and coordination in support of booster study areas.

    b. Provide booster D&C and C/W functional requirements, crew interface criteria, vehicle/interface constraints, and baseline update data as required.

    c. Update and provide the preceding data as required by study plan.

    d. Evaluate alternative concepts and practices.

    e. Document final.

4. Establish preliminary booster performance characteristics. Identify equipment interface parameters, including weight, power, volume, form, environment control requirements, and signal characteristics, including type, level, timing, etc. Establish subsystem cost and schedule impacts and support research and technology requirements. Prepare subsystem performance and interface specifications to include technical data for system specifications and for ICD's.

WBS Number: 3.3.2.4
Booster Tasks (Cont)

5. Provide crew systems safety data to support a system safety analysis for the booster electromechanical and integrated avionics subsystem.

6. Provide inputs in support of the booster failure mode effects analysis (FMEA).

SPACE SHUTTLE PHASE B
TASK DESCRIPTIONS

WBS TITLE: COMMUNICATIONS

WBS Number 2.3.2.5
Integration Tasks

Company:	Function:	Manager:
NR	Integrated Avionics	G. C. Anderson

1. Perform a comparison study of the updated orbiter and booster functional requirements and categorize identical and/or similar communication requirements for both vehicles to assure usage of common equipment.

2. Investigate and recommend frequency spectra and frequency allocations on the booster and orbiter to assure subsystem compatibility and optimum frequency utilization. Perform the necessary coordination with NASA, FAA (FCC), and in-house departments. Provide inputs to space shuttle system ICD's.

3. Conduct an analysis using trade study results of the recommended antenna locations on the orbiter and booster to determine function and physical compatibility.

4. Define and document electromagnetic interference (EMI) control and criteria for design and verification for the space shuttle system (orbiter and booster). The study will be based on mission objectives and applicable EMI specifications and standards. In addition, analyze:

    a. EMI limits for power buses

    b. Single- versus multiple-point grounds

    c. Design criteria for lightening protection

    d. Interference from spark-ignition systems

    e. Compatibility of low-level signals

WBS Number: 2.3.2.5
Orbiter Tasks

Company:	Function:	Manager:
NR	Integrated Avionics	G. C. Anderson

1. Establish communications subsystem requirements and define functional performance of the communication subsystem.

2. Perform the following studies and document the results for the application to the contract effort.

   a. Shuttle/ground communication interfaces (trade study)

   Define a communications subsystem concept that satisfies requirements for voice, data, tracking, and navigation- and landing-aid links between space shuttle vehicles and ground facilities, both direct and via communication satellites. Ground stations, ATC (civil, military), MSFN, reduced MSFN, and other capabilities will be evaluated and the required support established. A rationale will be developed for the required support.

   Based on defined requirements, a determination will be made of the degree of utilization of a compatible stationary satellite system. The NASA-provided definition/requirements for a mid-1970 communications satellite will be used in this study.

   b. Shuttle/space station - base communication interfaces

   Define a communications subsystem concept that satisfies requirements for voice, data, and tracking links between orbiter and space station-base. The study will be used on the in-house-developed requirements for the shuttle as the logistics vehicle for a space station/base, and on the space station communications and avionics data to be provided by NASA.

   c. Shuttle/booster communications interfaces

   Define a communications subsystem concept that satisfies requirements for voice and data-transfer capability between the shuttle and booster vehicles. RF, optical, inductive, and capacitive links will be investigated.

WBS Number: 2.3.2.5
Orbiter Tasks (Cont)

d. Shuttle - payload communication interfaces

Define a communications subsystem concept that satisfies requirements for voice hardwire bus between the shuttle and payload.

e. RF signals and modulation techniques

Evaluate and determine optimum modulation techniques and signal strength (signal margins) as a function of the orbiter mission and the defined communication interfaces external to the shuttle. The expected RF blackout during shuttle ascent and reentry will be considered.

f. Derivation of candidate subsystem concepts for the orbiter communications function

Function	Alternatives and Variables	Approach and Considerations
Orbiter two-way voice and data transfer	USBE, VHF/AM, VHF/FM, advanced S-Band, or combination with frequency synthesizers, etc.	Derive subsystem concepts based on performance, low cost, minimum development risk (off-the-shelf hardware where possible), flexibility, reliability, complexity, maintenance requirements, experience, power, weight and volume, availability, and optimum interface compatibility with the other subsystems internal and external to the orbiter vehicle.
Atmospheric Navigation and landing aids	Standard FAA-certified state, SPN-42, DME, VOR navigation satellite, microwave scanning beam ILS, TACAN	
Orbiter intercom	Apollo-type, military, commercial, modified, new, or other	
Acquisition and Tracking of passive targets for rendezvous	Range radar, range and angle radar, laser, TV, IR, or combination	

WBS Number: 2.3.2.5
Orbiter Tasks (Cont)

Function	Alternatives and Variables	Approach and Considerations
Rendezvous and docking aids for cooperative targets	VHF/AM, USBE as a transponder or working in conjunction with PRN ranging generator, or laser, TV, optic, radar, combination, or other	

g. Antenna subsystem evaluation for atmospheric and space application

Element and Function	Alternatives and Variables	Approach and Considerations
High-gain antennas for long-range and/or high data-rate transmission and/or passive target acquisition and rendezvous	Electrically steerable arrays, mechanically steerable arrays, deployable (dishes, helices) other conformal fixed arrays, replaceable, reusable	Derive and document rationale for candidate antennas and related equipment based on performance, low cost, minimum development risk, flexibility, availability, experience, and suitability for structural and thermal integration with the orbiter vehicle.
Antennas for atmospheric navigation and landing aids	Military, commercial, combination, modified, new, multifrequency	
Wide beam-width antennas for voice and low data rate (0 to 8 db)	Apollo, Saturn, or other NASA programs, military, modified or new	
Antenna window materials for orbiter antenna protection	Fused silica/quartz, polyimide and quartz fibers, other	

WBS Number: 2.3.2.5
Orbiter Tasks (Cont)

Element and Function	Alternatives and Variables	Approach and Considerations
Microwave Passive devices for interconnection of antennas with transmitters and/or receivers	Wave guide/coaxial transmission lines, isolators, circulators, power dividers, directional couplers, frequency passive multiplexers, other; NASA developed for space application, military, commercial, or special	

h. Antenna locations determination

The optimum antenna locations on the orbiter will be determined analytically. Planning will be prepared for future verification of locations on an antenna test range.

i. RF-link operational modes

Operational modes for the selected RF links will be established; a mode matrix showing alternate paths and switching requirements will be derived and documented.

j. Communications equipment interfaces

Optimum physical and functional interfaces will be derived and defined between the communications subsystem and other orbiter subsystems such as COFI, GN&C, DCM, structures, and environmental subsystem.

3. Selection of a recommended communications subsystem

The selection of a communications subsystem will be performed based on the results of trade studies. A weighted score will be established for comparison and evaluation of candidate equipments and/or subsystems. The weighted score will include such parameters as performance, cost, volume, weight, power, maintainability, development risk, complexity, availability, history, redundancy, and compatibility with the shuttle system. The evaluation process will be documented, and the rationale for the selection of a recommended communications subsystem will be presented.

WBS Number: 2.3.2.5
Orbiter Tasks (Cont)

4. Establish preliminary performance characteristics. Devise equipment interface parameters, including weight, power, volume, form, environmental control requirements, and signal characteristics, including type, level, timing, etc. Establish subsystem cost and schedule impacts and support research and technology requirements. Prepare subsystem performance and interface specifications to include technical data for preliminary specification and for ICD's.

5. Provide safety data to support a system safety analysis for all aspects of the electromechanical and integrated avionics subsystem.

6. Provide inputs in support of failure mode effects analysis (FMEA).

7. Perform integration functions which include technical and administrative liaison.

8. Support the booster Phase B effort.

Company:	Function:	Manager:
NR	System Engineering	J. Bates

9. In support of the shuttle ground communication interface tradeoff study, provide baseline and alternative mission profiles and the required communication coverage slant ranges including landing:

   a. Using the defined ground station requirements in WBS 2.3.2.5, determine number, type, locations and capabilities of present ground stations to be available for limited support of the Space Shuttle Program (near-earth orbits).

   b. Using the defined requirements for voice or data transfer via communications synchronous satellite system (WBS 2.3.2.5), determine which systems (NASA, military, and commercial) are capable of supporting these requirements.

10. Formulate communication transfer requirements between space station and base and the orbiter, including frequency, data rates, etc. Provide mission relationship (flight trajectories and slant ranges) between space shuttle and space station and base.

WBS Number: 3.3.2.5
Booster Tasks

Company:	Function:	Manager:
GD	Integrated Avionics	C. E. Grunsky

1. Assist NR in the integration tasks as detailed in WBS 2.3.2.5, Integration Tasks.

2. Establish the booster-peculiar communication subsystem requirements and assist NR in the establishment of booster/orbiter common requirements.

3. Assist NR in the performance of the shuttle/ground communication interfaces trade study detailed in WBS 2.3.2.5, Orbiter Tasks.

4. Assist NR in selecting a recommended communication subsystem and in establishing preliminary performance characteristics as detailed in WBS 2.3.2.5, Orbiter Tasks. Make any necessary changes to adapt this common design for the booster.

5. Provide communication-subsystem-related, booster-peculiar safety data and assist NR in the generation of booster/orbiter common safety data to support a system safety analysis.

6. Provide communication-subsystem-related, booster-peculiar inputs and support NR in the generation of booster/orbiter common failure mode effects analysis (FMEA).

SPACE SHUTTLE PHASE B
TASK DESCRIPTIONS

WBS TITLE: POWER DISTRIBUTION AND CONTROL

WBS Number: 2.3.2.6
Integration Tasks

Company	Function:	Manager:
NR	Integrated Avionics	G. C. Anderson

1. Define the common booster/orbiter integrated power distribution and control (PDC) requirements and functions. Requirements defined for integration of PDC shall include interface between booster/orbiter, requirements for use of common design approaches, electrical power characteristics, and hardware.

2. Integrate power distribution, conversion, distribution, and control formal trade study.

   a. Define common elements of booster/orbiter model baseline PDC subsystem using the following data:

      (1) Phase B proposal subsystem baseline

      (2) Common subsystem power quantity and quality requirements

   b. Using the results of the trade study matrixes and recommended option for each issue developed in 2.3.2.6, Orbiter Tasks, and 3.3.2.6, Booster Tasks, select option for each trade study issue which is optimum for integrated booster-orbiter considerations.

   c. Determine and report selection rationale and resulting integrated design and performance data.

3. Establish PDC integrated point design, defining common power characteristics, design approaches, and PDC hardware usage. Determine effects on integrated PDC of other trade study results (2.3.2.1, IAS Integration Tasks: Modular Design, Redundancy Techniques, Sensors and Actuators, and Integrated Vs. Conventional Avionics System Comparison). Establish PDC program costs and schedule impacts. Prepare integrated PDC requirements for space shuttle system specification.

WBS Number: 2.3.2.6
Integration Tasks (Cont)

4. Perform necessary analysis and studies to define the candidate types of electrical hardware/equipment for application to the space shuttle system, both orbiter and booster vehicles. Consideration will be given to conventional wiring techniques versus flat conductor cable in addition to other lightweight conductors and insulating materials. Candidate hardware for use in Phase C/D will be identified.

WBS Number: 2.3.2.6
Orbiter Tasks

Company	Function:	Manager:
NR	Integrated Avionics	G. C. Anderson

1. Define the functions and requirements of the orbiter PDC. Establish functional characteristics and functional block diagrams.

2. Perform the orbiter and common elements of the power conditioning, conversion, distribution, and control trade study.

   a. Conduct an industry and Government survey of current and advanced technology for PDC and utilization equipment. Obtain design and performance data.

   b. Define an orbiter model baseline PDC subsystem using the following data:

      (1) Phase B proposal subsystem baseline

      (2) Subsystem measurement and control requirements

      (3) Subsystem power quantity and quality requirements

      (4) Power system electrical load analysis and profile

   c. Using the model PDC subsystem and the data base developed from the PDC technology survey, define a study baseline PDC against which the effects of the options will be analyzed.

WBS Number: 2.3.2.6
Orbiter Tasks (Cont)

d. Establish a trade matrix for each of the issues listed in the trade study table, Table 2.3.2.6. The "options" of the trade table are the alternatives" of the matrix; the "considerations/parameters" are the matrix "objectives."

e. Recommend an option for each issue using trade study results.

f. Report selection rationale and resulting orbiter and common PDC design and performance data.

3. Establish a Phase B orbiter PDC subsystem Point Design, integrating the results of the trade study in Item f above and other trade studies which may affect PDC baseline design (e.g., WBS 2.3.2.2, Data and Control Management; 2.3.2.1, IAS Integration; and 2.3.6, Power Systems).

   Establish preliminary performance characteristics and interface parameters including weight, power, volume, and environmental control requirements. Establish orbiter PDC subsystems cost and schedule program impacts and supporting research and technology requirements. Prepare orbiter PDC inputs to IAS orbiter subsystem design data book, System Definition Handbook, Orbiter CEI System Specification Handbook, Orbiter CEI System Specifications, and ICD's.

4. Provide safety data to support an orbiter PDC subsystem safety analysis.

5. Provide inputs in support of failure mode effects analysis (FMEA).

6. Coordinate orbiter/booster external/internal lighting requirements. Perform necessary analysis and studies to establish design baseline configuration for crew/passenger compartment lighting and external lighting.

7. Coordinate the electrical design for all subsystems. Prepare simplified system electrical schematic diagrams for all subsystems to the degree required for Phase B definition.

8. Perform studies to evaluate existing and future techniques for avionic equipment installation and packaging techniques in order to adequately define and configure orbiter/booster equipment and equipment bays.

9. Coordinate wiring installation requirements to assure that provisions for wiring are incorporated in the overall vehicle design.

WBS Number: 2.3.2.6
Orbiter Tasks (Cont)

Table 2.3.2.6. Power Condition, Conversion, Distribution, and Control Trade Study

Issues and Options (Baseline)	Common Considerations/ Parameters	Orbiter Parameter
1. Distribution voltage, quality and type: 115/200 vac, 28 vdc, 115/200 vac, high-volt dc (56-280 V), all high-volt dc (56-280 V)	1. Power source, distribution, and load; paralleled/ isolated operations, efficiency, high-voltage-equipment availability safety, corona, development requirements	Weight, power, volume, cost, Risk
2. Power conversion: centralized, de-centralized; limited to conversion between levels selected in 1	2. Number of development types, efficiency, load diversification, system flexibility, complexity, EMI, load-growth provisions, reliability, power quality, integration, equipment availability	
3. Load control and protection devices: solid state, electromechanical	3. Response time, signal power, current and voltage transient control, voltage drop, heat dissipation, integration with IAS	
4. Bus configuration: synchronizing, load switching, or ring bus	4. Reliability, complexity, operational characteristics, source and load redundancy, power interruption requirements	
5. Power return path: wire, single-point ground; structure, multipoint ground	5. EMI, voltage drop, complexity, bonding, structure resistance, lightning protection	

WBS Number 3. 3. 2. 6
Booster Tasks

Company:	Function:	Manager:
GD/C	Integrated Avionics	C. Grunsky

1. Manage the trade study described in 2. 3. 2. 6, and as outlined below, and integrate results.

2. Define the functions and requirements of the power distribution and control subsystem. Establish mission impacts and establish functional characteristics and block diagrams.

3. Perform the booster elements of the power conditioning, conversion, distribution, and control trade study.

   a. Define a model PDC subsystem for the booster using the following data.

      (1) Phase B proposal subsystem baseline

      (2) Subsystem measurement and control requirements

      (3) Subsystem power quantity and quality requirements

      (4) Subsystem load analysis and profile.

   b. Using the booster model PDC subsystem and the data base developed from the PDC technology survey (see 2. 3. 2. 6), define a study baseline against which the effects of the options will be analyzed.

   c. Establish a trade matrix for each of the issues listed in the trade study table (Table 2. 3. 2. 6). The "options" of the table will be treated as alternatives in the trade matrix; the "considerations/parameters" become the matrix "objectives." Using a matrix and weighting factors provided by Systems Engineering, recommend an option for each issue using trade study results.

   d. Document and support selection rationale and resulting PDC design and performance data.

WBS Number 3.3.2.6
Booster Tasks (Cont)

4. Establish a booster PDC point design including the impact of other trade studies (e.g., Data and Control Management, 3.3.2.2; IAS Integration, 3.3.2.1; Power System, 3.3.5; and Unmanned Vs. Manned Booster).

   Prepare equipment interface parameters including weight, power, volume, form, and evnironment control requirements. Establish subsystem cost and schedule impacts on the program. Determine research and technology support requirements.

   Prepare subsystem performance and interface specifications, including technical input data for system specifications, ICD's, subsystem design data book, and System Definition Handbook. In addition, studies will be conducted to define the requirements and point design for internal and external lighting.

5. Provide safety data to support a booster PDC subsystem analysis as described in WBS 3.1.4.

6. Provide inputs in support of FMEA as defined in WBS 3.1.8.

SPACE SHUTTLE PHASE B
TASK DESCRIPTIONS

WBS TITLE: SOFTWARE

WBS Number: 2.3.2.7
Integration Tasks

Company:	Function:	Manager:
NR	Integrated Avionics	G. C. Anderson

1. Evaluate and approve results of IBM software design and trade studies so that a technical position on a software baseline may be recommended.

2. Prepare technical status briefings on software for NR management and for NASA throughout the Phase B study.

3. Provide technical coordination between GD/C, IBM, HI, and NR ICD's related to software.

4. Provide technical coordination with ERB on items related to software baseline.

5. Provide technical coordination with other engineering groups to assure timely delivery of data required for software studies (flight control, engine control, mission planning, checkout, etc.). Submit and control data forwarded to IBM.

6. Provide technical coordination with other engineering groups to assure the derivation of date (i.e., subsystem performance requirements) in proper format from software studies to satisfy their needs.

7. Study and evaluate design objectives so that software studies properly influence vehicle and subsystem design.

8. Provide safety data to support a system safety analysis for all aspects of the EM/IAS. Identify and document concepts and procedures where malfunctions may cause hazardous conditions.

9. Provide inputs in support of failure modes effects analysis (FMEA).

WBS Number: 2.3.2.7
Integration Tasks (Cont)

10. Define the functions and requirements of common orbiter/booster software for the EM/IAS subsystem, which included GN&C, communications, data and control management, on-board checkout (failure isolation, failure prediction, caution and warning) integrated displays and controls, and power distribution and controls, and for Shuttle Program ground systems.

11. Direct the activity and establish the requirements for the development of an overall software plan based on analysis of cost and schedule. Prepare software development schedule, referencing key Shuttle Program milestones.

12. Support the booster Phase B effort.

WBS Number: 2.3.2.7
Orbiter Tasks

Company:	Function:	Manager:
NR	Integrated Avionics	G. C. Anderson

13. Define the functions and requirements of the orbiter-peculiar software for the EM/IAS subsystem, which includes rendezvous, docking, payload monitoring, and communication with space station.

14. Perform software/hardware functional allocation. Establish mission impacts, define hardware/software interfaces, establish and define vehicle-ground system software interfaces, and establish functional characteristics and functional block diagrams of candidate software concepts.

15. Establish preliminary performance characteristics. Devise software interface parameters. Establish cost and schedule impacts.

16. Provide safety data to support a system safety analysis for all aspects of the electromechanical and integrated avionics subsystem.

17. Provide inputs in support of failure modes effects analysis (FMEA).

18. Perform subsystem integration functions that include technical and administrative liaison.

19. Direct and monitor in depth the subcontractor tasks described in the IBM subcontractor support portion of WBS 2.3.2.7.

WBS Number: 2.3.2.7
Orbiter Subcontractor Tasks

Company:	Function:	Manager:
IBM	Integrated Avionics	L.A. Jacowitz

20. IBM will perform a trade study to determine the impact of new higher order programming languages upon the projected shuttle development and operation plans. Documentation submitted in support of trade studies will include Kepner-Tregoe-type matrices and supporting data.

21. IBM will support the NR orbiter task for software/hardware functional allocation and interface definition as described in WBS element 2.3.2.7, Item 14.

22. Perform software/computer hardware sizing and timing analysis, using the simulation tools GPSS and/or CSS model software/computer configuration concepts.

23. IBM will support the NR orbiter task for development of data for system specifications and ICD's.

24. Establish support research and technology requirements.

25. Define a software management development plan. This plan defines and/or establishes the requirements for:

    a. Software documentation requirements which include the program performance specification, the program design specification, the detail subprogram design specification, the data base design specification, the program operating manual specification, the program test plans and test procedures specification, and the test program specification.

    b. Software visibility, design, and change control plan.

    c. The IAS system/subsystem dependency matrix and the IAS integration schedule.

    d. Software validation in the laboratory and operational environment.

WBS Number: 2.3.2.7
Orbiter Subcontractor Tasks (Cont)

26. Define and/or establish the requirements for system support software which includes:

    a. Higher order language (CMS-2, SPL, etc.)

    b. On-board master executive program (function manager, task schedules, I/Ø supervisors, interrupt processor).

    c. Systems utility routines

       Emulators
       Simulators
       Assemblers
       Loaders
       Editors

27. Investigate the feasibility of using existing software or the design of existing software.

28. Provide software-related safety data to support an EM/IAS safety analysis as described in orbiter WBS 2.3.2.7.

29. Provide software-related failure modes effects analysis data to support Orbiter WBS 2.3.2.7.

30. Provide support for formal design reviews scheduled with NASA during the Phase B study. IBM will support these reviews by attendance and by submittal of a data package.

WBS Number: 3.3.2.7
Booster Tasks

Company:	Function:	Manager:
GD/C	Integrated Avionics	C. E. Grunsky

1. Define the functions and requirements of the booster-peculiar EM/IAS subsystem software, which includes EC/LSS, electrical power generation, flight control, and navigation.

WBS Number: 3.3.2.7
Booster Tasks (Cont)

2. Provide software-related booster-peculiar safety data to support a system safety analysis for all aspects of the EM/IAS subsystem, as defined in WBS 2.3.2.

3. Provide software-related booster-peculiar inputs in support of failure modes effects analysis as defined in WBS 2.3.2.

4. Perform subsystem integration functions that include technical and administrative liaison as defined in WBS 3.3.2.

5. Support the functions and requirements definition as described in integration tasks, WBS 2.3.2.7, Item 10.

6. Support software/hardware functional allocation and interface definitions as described in WBS 2.3.2.7, orbiter, Item 14.

7. Support development of software plan as described in WBS 2.3.2.7, integration tasks, Item 11.

8. Support software-related safety data as described in WBS 2.3.2.7, orbiter, Item 16.

9. Support software-related failure modes effects analysis as described in WBS 2.3.2.7, orbiter, Item 17.

10. Support the direction and monitoring of subcontractor tasks as described in WBS 2.3.2.7, orbiter, Item 19.

11. Develop and document a software validation methodology to support IBM subcontractor, WBS 2.3.2.2.

SPACE SHUTTLE PHASE B
TASK DESCRIPTIONS

WBS TITLE: CHECKOUT AND FAULT ISOLATION

WBS Number: 2.3.2.8
Integration Tasks

Company:	Function:	Manager:
NR	Integrated Avionics	G. C. Anderson

1. Provide technical coordination with other engineering groups to assure availability of data (i.e., measurement and control lists, functional block diagrams, etc.) in formats compatible with study needs.

2. Provide technical coordination with other engineering groups for delivery of data developed through COFI studies.

3. Analyze, evaluate, and approve results of IBM trade and design studies so that the COFI technical baseline configuration may be updated and controlled in a timely manner.

4. Provide technical coordination between GD/C, IBM, HI, and NASA.

5. Prepare and maintain current technical briefings on COFI for NR management and NASA throughout Phase B.

6. Provide technical coordination with ERB on items related to COFI baseline.

7. Provide technical coordination with AA to insure that airline maintenance concepts applicable to COFI are implemented to the optimum degree.

8. Coordinate and support development of trade study evaluation criteria and weighting factors with systems engineering.

9. Provide safety data to support a system safety analysis for all aspects of the electromechanical and integrated avionics subsystem.

10. Provide inputs in support of failure modes effects analysis.

WBS Number: 2.3.2.8
Orbiter Tasks

Company:	Function:	Manager:
NR	Integrated Avionics	G. C. Anderson

11. Define the functions and requirements of the orbiter on-board checkout and fault isolation subsystem. Establish mission impacts, identify critical failure modes, define hardware/software interfaces, establish and define IAS/vehicle subsystem interfaces, and establish functional characteristics and functional block diagrams of candidate subsystem concepts. Define the redundancy required within the COFI subsystem in terms of redundant measurement and control paths necessary to meet FO/FO/FS criteria.

12. Determine the desirability and feasibility of incorporating built-in test and built-in self-test features in the systems design. Define hardware self-test concepts. Define desired test levels, display, and recording requirements, extent of trend data analysis, and extent of crew participation in testing. Determine the best of various methods for injecting test signals into an instrumentation subsystem for the purpose of determining validity of operation including redundant paths.

13. Provide technical directions, control and integration of associate and subcontractor efforts in subsystem level analysis, definition, and design including:

    a. Analysis, definition, and integration of booster checkout and fault isolation (COFI) requirements. This effort will be accomplished with NR and GD/C participation as shown in Table 1.

TABLE 1.

WBS Area	NR	GD/C
Aero surfaces	B	B
Vehicle struct	B	B
Therm prot	B	B
Main prop	S	P
Orb man.	P	
ACPS	B	B
Air breath	B	B
Cryo tanks	B	B
GN&C	P	S

*P = Prime
S = Support
B = Both

WBS Number: 2.3.2.8
Orbiter Tasks (Cont)

TABLE 1. (Cont)

WBS Area	NR	GD/C
DCM	P	S
ID/C	P	S
Comm	P	S
Elec pwr	P	S
Hyd pwr	S	P
ECLSS	B	B
Landing	B	B
Docking	P	-
Booster mate/sep	S	P
Payload	P	-

*Prime analysis responsibility is assigned to either GD/C or NR with support from the other, when the checkout tasks are the same or quite similar, i.e., when a booster subsystem is a subset of the orbiter subsystem, or vice versa. Dual responsibility is assigned when the checkout tasks in the orbiter and booster differ significantly, i.e., when significant differences exist between the subsystems.

b. IBM analysis, definition, and design for the COFI subsystem. IBM tasks relative to COFI are defined under the subcontractor section of WBS 2.3.2.8.

14. Establish appropriate design standards and hardware and software performance/integration criteria for COFI. Define the optimum COFI design.

15. Plan, direct, and coordinate associate and subcontractor support to an on-board checkout techniques trade study that encompasses the issues outlined in Paragraph 12.

a. Options and Major Issues

Issues	Options
(1) Extent of on-board checkout capability	Limited (ground oriented); to level of redundancy application; LRU level; sub-LRU level.
(2) On-board checkout implementation techniques	Centralized; partially decentralized; decentralized; Built-in-test equipment (BITE)

WBS Number: 2.3.2.8
Orbiter Tasks (Cont)

Issues	Options
(3) Crew participation	Executive control (highly automated) active participation; parameter decisioning except routine functions. Manual control of checkout and fault isolation.
(4) Trend data analysis	On-board pseudo-realtime trend analysis; ground analysis of recorded flight data.
	Extensive trend analysis for all subsystems; trend analysis for selected subsystem components.

b. Trade study subtasks

(1) Establish and document COFI criteria and guidelines based on the RFP, baselines expressed in formal proposal submission, and basic information obtained from preliminary subsystem analyses.

(2) Categorize checkout requirements into three main groups based on data from other subsystem and system engineering groups:

(a) Those that are required on board for flight operations and are, therefore, not tradable.

(b) Those that are not feasible for on-board implementation.

(c) Those that may be implemented either on-board or through ground techniques (this latter category will then represent the tradable tasks).

(3) Define alternate checkout concepts to accomplish mandatory tasks on-board. Define alternate ground checkout concepts for all non-mandatory checkout tasks to provide a basis for

WBS Number: 2.3.2.8
Orbiter Tasks (Cont)

comparison of costs. Checkout tasks that are not feasible to implement onboard will influence the final concept selection only to the extent that they constrain the possible ground checkout concepts. Define software approach for each alternative to the same degree that hardware is defined.

(4) Establish trade factor weighting and evaluate alternative concepts. Determine the optimum division of onboard/ground tasks and furnish these results as inputs to other trade studies (i.e., centralization of functions, flight systems optimization).

(5) Compare the results of the On-board versus ground trade study with results from other trade studies, principally Centralization of Functions, to determine any existing incompatibilities. Iterate the on-board versus ground trade to resolve incompatibilities.

(6) Refine the on-board checkout implementation criteria to define the extent of crewman availability for participation in checkout, display, and recording requirements, trend analysis requirements--both on-board and on the ground, test levels, and ground interfacing requirements.

(7) Categorize the on-board checkout tasks into three groups:

(a) Those that must be accomplished within a subsystem LRU.

(b) Those that must be accomplished on a centralized basis.

(c) Those that may be accomplished in either manner and are, therefore, tradable.

(8) Establish trade factor weighting and evaluate alternative concepts. Determine the optimum division of BITE/centralized checkout tasks along with the extent of crewman participation, recommended test levels, trend analysis capabilities, and display and recording requirements. Factors that will influence these decisions include the following: safety, total program cost (including sustaining manpower), risk, software

WBS Number: 2.3.2.8
Orbiter Tasks (Cont)

complexity, flexibility and growth capability, effects of power, weight, and volume. Furnish the results of this trade as inputs to other trade studies.

(9) Review and compare results obtained with data from other trade studies, primarily centralization of functions. Iterate the trade to resolve incompatibilities.

(10) Document selected concepts including all selection rationale.

16. Analyze the development flight instrumentation (DFI) requirements for impact on operational checkout systems in terms of both hardware and software. Determine the best conceptual approach for accommodating DFI with respect to signal transducers, conditioners, multiplexers, processors, and recorders and/or telemetry subsystems, including power requirements and location constraints. Determine the philosophy to be implemented for removal of DFI upon termination of the test program.

WBS Number: 2.3.2.8
Orbiter Subcontractor Tasks

Company:	Function:	Manager:
IBM:	Integrated Avionics	L. Jackowitz

17. Perform the following representative tasks: requirements analysis, parametric studies, concepts definition and evaluation, candidate hardware configuration and preliminary specifications, supporting analysis, design and development planning, and program planning related to the COFI function.

18. Configuration analysis: provide support for COFI configuration in the following areas:

   a. Location constraints of COFI-critical components including installation interfaces.

   b. Operating conditions, environments, and procedures required for hardware.

   c. Definition of weight, power, volume, and form requirements.

WBS Number: 2.3.2.8
Orbiter Subcontractor Tasks (Cont)

d. Definition of any special calibration and instrumentation requirements and equipment.

e. Requirements for maintenance and repair.

19. Perform system analyses to develop alternative approaches, perform tradeoff studies, and analyze program impacts to identify a preferred COFI design.

20. Perform COFI configuration definition and redundancy studies, identify and evaluate alternative approaches, perform tradeoff studies to select baseline approach. Conduct optimization studies to define approach.

21. Provide the analysis and preliminary design of COFI subsystem hardware and software, including new and modification of existing equipment for:

a. Ground equipment and facilities required for preparation and launch.

b. Ground equipment and facilities for conduct of mission operations.

22. Perform preliminary design for the hardware, software, and procedures to implement the selected COFI subsystem design, including the following:

a. COFI computer equipment assemblies.

b. Computer programs, including common instruction lists.

c. COFI displays and control assemblies.

d. On-board checkout assemblies.

e. COFI remote acquisition, control, and test assemblies.

f. Define research and technical programs to develop ground and flight COFI equipments if necessary.

g. Provide support to the long life assurance analysis effort.

WBS Number: 2.3.2.8
Orbiter Subcontractor Tasks (Cont)

h. Provide support to the development of test philosophy by analysis of costs, timing, test, and effectiveness within guidelines established for the Space Shuttle.

23. Support NR crew operations analysis in the area of crew participation in checkout and fault isolation activities.

24. Provide analysis for preliminary definitions of the subsystem hardware and software for ground testing, checkout, launch, orbit support, and recovery operations.

25. Conduct the following specific studies:

a. On-board versus ground checkout and fault isolation.

b. Degree of checkout function integration with DCM.

c. Integrated versus BITE testing.

d. Centralized versus decentralized checkout.

e. Checkout participation in redundant mode selection.

f. Automated decision making versus crew selection of operational mode.

g. Trend analysis significance versus multiple redundancy requirements.

WBS Number: 3.3.2.8
Booster Tasks

Company:	Function:	Manager:
GD	Integrated Avionics	C. E. Grunsky

1. Assist NR in the continuing development of the COFI philosophy and the COFI application criteria.

2. Provide booster-unique data and assist NR in providing booster/orbiter common data to support the system safety analysis.

WBS Number: 3.3.2.8
Booster Tasks (Cont)

3. Provide booster-unique data and assist NR in providing booster/orbiter common data to support a failure mode effects analysis (FMEA).

4. Assist NR in the development of the booster/orbiter common COFI subsystem predesign data.

5. Determine booster-peculiar requirements and assist NR in determining booster/orbiter common requirements for the COFI subsystem.

6. Assist NR by analyzing orbiter-peculiar requirements and predesign data to assure maximum commonality between orbiter and booster COFI subsystems.

7. Support NR in the integration functions which include technical and administrative liaison between associated team members and the various agencies of the customer and to assist NR in the preparation of program documentation and preparation and presentation of program data at briefings, meetings, intercenter conferences, etc.

8. Support NR in the evaluation of existing computer development simulation programs.

9. Support NR in developing the best approach to accommodating DFI. Perform analysis on booster-unique DFI requirements.

SPACE SHUTTLE PHASE B
TASK DESCRIPTIONS

WBS TITLE: LANDING SYSTEM

WBS Number: 2. 3. 3
Integration Tasks

Company:	Function:	Manager:
NR	Preliminary Design	W. A. Martin

1. Coordinate orbiter/booster design criteria and investigate utilizing equipment and components common to orbiter and booster landing systems.

2. Provide support to System Integration Task 1.2 through design definition of orbiter and booster design concepts.

WBS Number: 2. 3. 3
Orbiter Tasks

Company:	Function:	Manager:
NR	Preliminary Design	W. A. Martin

3. Define in the form of preliminary design sketches and layouts the mechanical landing gear components of the orbiter vehicles of the space shuttle system. The components defined will include both main and nose landing gear struts, wheels, brakes, tires, tubes, retraction and extension mechanism, trunnions, braces, and installation provisions.

4. Delineate requirements used in the design task defined above.

5. Conduct a hazards and failure mode effects analysis of the mechanical landing system defined above for normal and emergency conditions.

WBS Number: 2. 3. 3
Orbiter Tasks (Cont)

6. Evaluate and document the results of the Company-sponsored design study, which includes the tasks outlined below:

   a. Define minimum acceptable landing surface condition, and list typical continental United States landing sites.

   b. Conduct runway flotation analysis studies to determine number of wheels, spacing, tire size, and pressure.

   c. Prepare curves showing relationship of sink rate and load factor versus gear vehicle weight and volume.

   d. Utilize preliminary dynamic and stress analysis and prepare shock strut load-stroke curves.

   e. Investigate alternate types of brake material, number-of-stops criteria, and TRO capability. Determine delta cost and weight and development risk.

   f. Investigate auxiliary deceleration and control devices, such as anti-skid and drag chutes, and determine delta weights and cost effect on landing distance.

   g. Prepare layouts of alternative landing gear geometry. Compare such things as turn-over angle, side loads, and percentage weight distribution, interchangeability of left- and right-hand gear.

   h. Define nose wheel steering system and performance requirements including travel limits and speed of operation.

7. Investigate wheel well environment data and its effect on shock-strut oil, gear actuation system, and tires. Determine door sealing requirements and need for conditioning of wheel well.

8. Establish ground handling criteria, ground loads, and justification for any limitation.

9. Establish preflight servicing and checkout requirements.

10. Prepare descriptions of system configuration, operating characteristics, and performance specifications for the overall vehicle specification document.

WBS Number: 3. 3. 3
Booster Tasks

Company:	Function:	Manager:
NR	Power and Fluids	D. Krause

Study landing systems design concepts, which will include vehicle dynamics and structural analysis with weight, volume, retraction stowage, and location considerations. Define the minimum acceptable landing surface compatible with the recommended landing system and list typical continental U. S. landing sites. Define deceleration devices.

1. Evaluate results of company-sponsored studies related to:

    a. Number of wheels, spacing, tire size and pressure

    b. Relationship of sink rate and load factor to gear and vehicle weight and volume

    c. Investigations of alternate brake materials, number-of-stops criteria and RTO capability and relationships of cost, weight, and development risk.

    d. Auxiliary deceleration and control devices such as anti-skid and drogue parachutes, including weight and cost effects on landing distance.

    e. Types of control systems for nose wheel steering, required travel limits, and speed of operations.

2. Conduct preliminary dynamic and stress analysis and prepare shock-strut load stroke curves.

3. Prepare layouts of alternative landing gear geometry and compare turnover angle, side loads, percentage weight distribution, interchangeability of left- and right-hand gear, etc.

4. Determine wheel-well environment and effect on shock-strut oil, gear actuation system, and tire material. Determine door-sealing requirement and need for conditioning wheel well.

WBS Number: 3.3.3
Booster Tasks (Cont)

Company:	Function:	Manager:
GD	Power and Fluids	D. Krause

5. Provide results of FMEA and safety and maintainability analyses.

6. Prepare description of system configuration, operating characteristics, and performance specifications for the overall vehicle specification document.

7. Establish preflight servicing and checkout requirements.

Company:	Function:	Manager:
GD	Mass Properties	R. L. Benson

Determine weight, installed center of gravity, installed moment of inertia, material designation, and SP6004 code. Prepare input for digital computer, review design for optimum weight, and establish target weights for weight control.

SPACE SHUTTLE PHASE B
TASK DESCRIPTIONS

WBS TITLE: DOCKING SYSTEM

WBS Number: 2.3.4
Integration Task

Company:	Function:	Manager:
NR	Preliminary Design	W. A. Martin

Review docking concept candidates and select one for predesign based upon total system effects--cost, performance, flexibility, safety, reliability, and growth. Assure integration of design data, dynamic loads, etc., developed under other WBS elements.

WBS Number: 2.3.4
Orbiter Tasks

Company:	Function:	Manager:
NR	Preliminary Design	W. A. Martin

1. Evaluate and document results of the company-sponsored docking concepts trade study for application to the contract effort. The company-sponsored trade study will:

    a. Define potential docking concepts for shuttle and space station.

    b. Consider modular as well as neuter versus male-female engagement concepts.

    c. Determine to what extent stabilization of docked orbiter/space station should be shared between them while docked.

    d. Generate potential techniques for retrieval of uncooperative satellites or for rendering satellites inoperative.

    e. Recommend docking concept.

WBS Number: 2.3.4
Orbiter Tasks (Cont)

2. Prepare sketches and preliminary design layouts of the docking system for the orbiter vehicles of the space shuttle system, from company-sponsored trade studies of space station docking and stabilization methods. The sketches and layouts will show provisions in the design for initial latching, interface rigidization, pressure sealing, initial relative motion arrest, and reusability.

3. Conduct a hazards analysis of the docking system defined above for the orbiter, crew, and passengers.

4. Conduct an FMEA of the docking system defined above.

Company:	Function:	Manager:
NR	Flight Technology	N. F. Witte

5. Identify crew task requirements during approach and docking operations and develop preliminary crew operational procedures. Identify candidates for both normal and backup modes, visual/optical alignment aids, and related human engineering requirements for preliminary design.

6. Evaluate and document results of the company-sponsored efforts described below:

    a. Select and develop design requirements of visual and optical alignment aids for gross attitude orientation, range, range rate, and final alignment on both the active and passive vehicles for all natural limiting conditions.

    b. Develop detail crew task descriptions (time lines) and control and display requirements for terminal rendezvous, docking mating, and separation.

WBS Number: 2.3.4
Orbiter Tasks (Cont)

Company:	Function:	Manager:
NR	Integrated Electronics	G. C. Anderson

7. Support Preliminary Design engineering in design of the docking system through identification of the docking aids to be used and definition of performance parameters, with constraints and limitations. Define the guidance and control system performance capabilities, constraints, and limitations to perform docking maneuvers. Provide tradeoff data pertinent to the docking system design.

SPACE SHUTTLE PHASE B
TASK DESCRIPTION

WBS TITLE: ENVIRONMENTAL CONTROL AND
LIFE SUPPORT SYSTEMS

WBS Number: 2.3.5
Integration Tasks

Company:	Function:	Manager:
NR	Fluids and Propulsion	R. E. Field

The contractor will analyze and define all elements involved in the environmental control, thermal control, water and waste management, and life support subsystems that are required on the space shuttle. This will include the environmental control and life support system (ECLSS) requirements and interface requirements for the cargo compartment.

The ECLSS must provide the following five functions:

a. Maintenance of a shirtsleeve environment--temperature, atmospheric pressure, and composition.

b. Water and oxygen supply.

c. Atmosphere revitalization.

d. Facilities for waste management.

e. Maintenance of the temperature of space shuttle equipment by dissipating heat and compensating for the varying thermal environment.

Specific tasks that will be accomplished are:

WBS Number: 2.3.5
Orbiter Tasks

1. Evaluate results of company-sponsored effort defined below:

   a. List ECLS candidate concepts and flight and GSE hardware for commonality between orbiter and booster.

WBS Number: 2.3.5
Orbiter Tasks (Cont)

b. Review computer tools for common system concept studies.

2. Support WBS 1.2 - System Integration by providing design and performance definition of related system concepts.

Company:	Function:	Manager:
NR	ECLSS	R. E. Field

3. Define baseline ECLS requirements for equipment and cargo bays. This will include crew and passengers, electronic equipment, space station, ground support, remote compartments, engine compartments, and wheel-well compartments.

4. Define baseline ECLS systems to the requirements of the contract statement of work. This will include environmental control system (ECLS) for crew, passenger compartment, and electronic equipment, waste management, food management, and water management. The following items will be given prime consideration in defining the baseline:

   a. Highly maintainable and refurbishable system and realistic system checkout techniques prior to reuse

   b. ECLSS thermal control concept to allow efficient vehicle operation from launch through reentry and postlanding

   c. Integrated ECS concept to allow optimum support of variable passenger loads, mission length, and design flexible enough to incorporate technical advances

   d. Waste management provisions for the crew

   e. Bacteriological control in a reusable system (particularly the water subsystem)

   f. Design integration of fire detection sensors, storage tanks, fluid and control for the crew station area

WBS Number: 2.3.5
Orbiter Tasks (Cont)

5. Define concept options tree and perform design studies for the following items:

   a. Effect on thermal control of 200- and 1500-nmi. vehicle cross-range requirement

   b. CO_2 subsystem trade study (LiOH versus molecular sieve)

   c. Humidity subsystem trade study (condensing heat exchanger techniques versus desiccant)

   d. Radiator configuration, location, thermal coating degradation, coolant selection, and associated refurbishment requirement considerations

   e. Heat transport loop configuration temperature control trade and design study, including consideration and optimization of coolant fluid.

   f. Prelaunch, launch, reentry, and postlanding thermal control design study

   g. Instrumentation requirements definition for ECLSS checkout, inflight status, abort, etc.

6. Develop work statements, review data, and coordinate with ECLS subcontractors to support above defined tasks.

7. Support conceptual trade study of space thermal control techniques.

8. Define recommended ECLS in terms of overall system configuration, specific subsystem selections, weight, power, volume requirements, etc.

9. Update and document ECLS interface requirements, prepare preliminary system specifications, prepare system level FMEA's, and document hazard analysis study.

10. Coordinate with NASA in review of ECLS options study and system selection.

11. Participate in location of life support equipment and crew and passenger compartment arrangement.

WBS Number: 2.3.5
Orbiter Tasks (Cont)

12. Prepare technical documentation and briefings in support of customer and management requirements.

13. Evaluate results of the company-sponsored concept options tree and design studies for the following items:

    a. Cabin temperature control trade study (direct atmospheric cooling versus wall cooling)

    b. Cabin pressure considerations

    c. Nitrogen supply trade study

    d. Suborbital heat rejection design study

    e. Window defogging design study

14. Evaluate results of the company-sponsored design studies that include the following tasks:

    a. Evaluate ECLSS performance for design and off-design conditions.

    b. Prepare configuration baseline for Phase B.

    c. Prepare configuration baseline for Phase C proposal.

    d. Prepare Phase B preliminary CEI.

    e. Prepare Phase B final CEI.

    f. Prepare Phase C proposal inputs and Phase C planning documents.

15. Prepare inputs to final Phase B Report.

WBS Number: 2.3.5
Orbiter Tasks (Cont)

Company:	Function:	Manager:
NR	Flight Technology	N. F. Witte

Define preliminary crew/passenger system and hygiene requirements for ECLSS, including atmospheric control, food and water systems, and waste management systems.

Evaluate and document results of related company-sponsored effort as defined below:

16. Perform analyses of logistics missions to identify the nature and magnitude of crew health problems, with particular emphasis on waste management, personal hygiene, and prevention of disease.

17. Define optimum crew health system options considering typical mission characteristics and system integration with ECLSS componentry.

18. Investigate crew health standards, including flight, preflight, and postflight considerations, for specific application to logistics missions. Delineate the allowable concentrations of toxicants and microorganisms in company with recommended system capabilities and techniques.

19. Investigate and identify potential crew and passenger environmental conditions - normal and emergency problem areas in advanced logistics spacecraft, including pressure, gaseous mixtures, structure and gas temperatures, airflow rates, humidity, odor, microbiological control systems, acoustics, radiation, and lighting. Consider support of incapacitated crewmen.

20. Develop candidate solutions for the critical conditions and determine related penalties and advantages. Continue research in predicting accident and sickness rates.

21. Perform trade studies to select optimum solutions for various typical advanced logistics missions. Identify research needs.

WBS Number: 2.3.5
Orbiter Tasks (Cont)

Company:	Function:	Manager:
NR	Vehicle Structures	R. A. Lusk

22. To support definition of the orbiter ECLSS, the Vehicle Structures group will analyze, define, and select insulation materials for system tubing, support selection of radiator coatings, and support selection of cabin wall coatings to reduce radiative heat transfer.

    As a function of the analytical support, curves will be provided showing weight and volume savings as a function of cabin pressure for the crew and passenger compartment.

WBS Number: 3.3.4
Booster Tasks

Company:	Function:	Manager:
GD	Power and Fluids	D. Krause

Define elements involved in environmental control, thermal control, water and waste management, and life support subsystems as required to maintain a shirtsleeve environment in the booster vehicle. Specific activities will consist of:

1. Evaluation of results of company-sponsored studies related to:

   a. Alternate methods of humidity and CO_2 control

   b. Determination of optimum cabin pressure with respect to vehicle weight and requirements and methods of O_2 replenishment to maintain a safe O_2 partial pressure

   c. Heat transport loop configuration temperature control trade/design study, including consideration and optimization of coolant fluids

   d. Alternate methods of providing ECLSS heat sink during all mission phases

WBS Number: 3.3.4
Booster Tasks (Cont)

e. Methods of providing redundancy and maintenance features consistent with requirements of a reliable, reusable, booster vehicle

2. Define recommended ECLSS in terms of performance, weight, volume, power mode of operation, maintainability, and reusability.

3. Determine heat transfer through structure and windshield and windshield defogging requirements.

4. Provide results of FMEA and safety and maintainability analyses.

5. Define instrumentation requirements for ECLSS checkout, inflight status, abort, etc.

6. Determine weight, installed center of gravity, installed moment of inertia, material designation, and SP6004 code. Prepare input for digital computer, review design for optimum weight, and establish target weights for weight control.

SPACE SHUTTLE PHASE B
TASK DESCRIPTIONS

WBS TITLE: POWER SYSTEMS

WBS Number: 2.3.6
Integration Tasks

Company:	Function:	Manager:
NR	Fluids and Propulsion	R.E. Field

1. Review booster/orbiter power system equipment to determine potential commonality items and identify these items.

2. Evaluate impact of commonality on system characteristics.

3. Recommend common equipment and degree of commonality in support of WBS 1.2 - System Integration.

4. Provide support to MSC fuel cell technology contracts with General Electric and Pratt & Whitney. Attend integration meetings and provide interface data.

5. Provide support to LeRC APU technology contracts. Attend integration meetings and provide interface data.

WBS Number: 2.3.6
Orbiter Tasks

Company:	Function:	Manager:
NR	Fluids and Propulsion	R.E. Field

1. Perform power generation and operations trade study tasks as outlined below, with Tasks c, g, and h conducted as company-sponsored activities to support the contract effort as applicable:

   a. Determine applicable subsystem power requirements, electrical and mechanical. Identify candidate loads and prepare nominal and emergency load profiles for the delta- and straight-wing orbiter configuration, including electrical and mechanical loads.

WBS Number: 2.3.6
Orbiter Tasks (Cont)

b. Evaluate use of hydraulic, pneumatic or electromechanical power for nose landing gear, cargo door, cargo deployment, and docking activation functions.

c. Evaluate alternate mechanical energy sources to provide the high-power, short-duration power for actuation functions. Alternates include turbine-powered APU's, monopropellant APU's, high-power-density fule cells/electric motors, and these approaches in combination with turbojet accessory power. Evaluate both high- and low-pressure turbines.

d. Evaluate alternate electrical energy sources to provide electrical power throughout the orbital and ferry missions. Alternates include fuel cells, turbine-driven generators, turbojet-driven generators, and combinations.

e. Determine emergency power requirements and evaluate candidate sources, including silver-zinc and nickel-cadmium batteries.

f. Conduct design studies on hydraulic system considering the following:

- System pressure: 3000 versus 4000 psi
- Number of systems for each load: 2 systems plus accumulator, 3 systems, 4 systems
- Use of individual hydraulic power packages or pneumatics for remote loads
- Hydraulic fluid, tube material, reservoir type
- Power source location

g. Evaluate design of hydraulic systems for use in space vehicles: (1) low-temperature insulation and heating concepts for long-term space storage; (2) high-temperature thermal isolation and heat rejection concepts during vehicle entry; and (3) minimization of peak and average power requirements to reduce the size of the prime power source and fuel consumption requirements. Evaluate high- and low-temperature hydraulic systems.

WBS Number: 2.3.6
Orbiter Tasks (Cont)

h. Evaluate application of high-voltage (56 to 280 volts) fuel cells to power electrical/avionic systems. Conduct weight trades, identify problem areas associated with fuel cell modules, and propose problem solutions.

i. Determine servo-actuator redundancy requirements considering single surfaces, split surfaces, single versus dual actuators, digital versus analog control, and fault isolation techniques.

j. Evaluate reactant storage and feed concepts as follows:

   (1) Separate

   (2) Combined APU, fuel cell, and ECLS requirements

   (3) Combined fuel cell and ECLS

   (4) Combined with propulsion tankage

   (5) Supercritical; subcritical--pump-augmented or low-pressure.

   Consider servicing, mission duration flexibility, ferry flight requirements, total and specific impurity effects, fluid and tank weights, and expulsion methods. Evaluate integrated thermal and fluid conditioning concepts.

k. Evaluate fuel cell type and life factors considering alkaline asbestos matrix, acid solid polymer, orbital shutdown, CO and CO_2 removal, and electrolyte flush.

l. Evaluate fuel cell heat rejection concepts, including separate and integrated concepts with ECLS system.

m. Evaluate impact of redundancy concepts:

   (1) Electrical power generation: FO/FO/FS versus FO/FS.

   (2) FS electrical power source for safe return from orbit: extra fuel cell, auto-activated battery, or APU's.

   (3) Tankage: nonredundant versus redundant concepts.

WBS Number: 2.3.6
Orbiter Tasks (Cont)

n. Prepare APU requirements and duty cycles resulting from above evaluations and document in accordance with Appendix F of RFP.

2. Perform gimbal system type and location trade study to determine the the type--hydraulic, pneumatic, electromechanical, or mechanical--and whether powered from the central hydraulic system or from independent engine systems. Evaluate methods for automatic return to locked null at engine or gimbal system failure and TVC prior to engine start. Document in accordance with Appendix F of RFP.

3. Perform preliminary design definition for selected power system concept, with Task h conducted as a company-sponsored activity to support the contract effort as applicable:

   a. Define subsystem performance and design requirements.

   b. Prepare subsystem schematics and size equipment to assembly level.

   c. Perform design option studies and preliminary design on control system, connections, and seals.

   d. Define measurement and stimuli requirements for monitoring and checkout.

   e. Conduct FMEA and hazards analysis on selected design. Evaluate turbine overspeed protection methods and minimization of hazards associated with APU exhaust.

   f. Evaluate subsystem installation concepts.

   g. Provide inputs to CEI, final report, design data book, development plans, SRT requirements, and ICD's.

   h. Develop computer simulation program for power generation system, including load profiles, generation equipment, feed system and reactant storage.

   i. Determine power profiles for flight test program requirements. Produce design recommendation to accommodate these requirements.

WBS Number: 2.3.6
Orbiter Tasks (Cont)

Company:	Function:	Manager:
NR	Integrated Electronics	G.C. Anderson

4. Determine electrical loads and duty cycles, electronic redundancy, and servo analysis for flight controls and engine gimbal system.

Company:	Function:	Manager:
NR	Flight Technology	N.F. Witte

5. Evaluate results of company-sponsored effort to define control surface operating loads deflection angles and hinge moments as affected by flow separation over the surfaces.

6. Define control surface operating loads, hinge moments, surface rates, and deflection angles for selected configurations.

WBS Number 3.3.5
Booster Task

Company:	Function:	Manager:
GD	Power and Fluids	D. Krause

Define electric, hydraulic, and pneumatic power generating systems, including APU, and prepare load analysis and power profiles.

1. Evaluate and utilize results of company-sponsored studies dealing with:

   a. Parametric studies on operating characteristics of various types of APU's, including monopropellant and high- and low-pressure H_2-O_2 units

   b. Types of reactant storage, supply, and conditioning systems for APU's considering low- and high-pressure cryogenic storage either separate or integrated with propulsion tankage, supercritical and pump-fed

WBS Number 3.3.5
Booster Task (Cont)

c. Alternate configurations of power generation systems including redundancies to meet various failure criteria with relative characteristics of weight and complexity

d. High- and low-temperature hydraulic systems including fluids, components, and cooling requirements.

2. Conduct power generation and operation trade study for actuation systems, auxiliary power, and electrical power. Actuation systems studies will compare hydraulic, pneumatic, and electric drives. APU and APU plus turbojet accessory power will be considered in determining the best auxiliary power source. Generators, batteries, and batteries plus generators will be evaluated for the electrical power source. Vehicle loads determined from aerodynamic and dynamic analysis, integrated electronic system requirements, and fluid systems' demands will be used in sizing alternate solutions. Selection will be based on weight, development risk and cost, performance, operational flexibility, and orbiter/booster commonality.

3. Determine servo-actuator requirements considering redundancy with single surfaces, split surface redundancy, single versus dual actuators, digital versus analog control, fault-isolation techniques, and location. Selection criteria will include servo-valve synchronization capability, response to hard-over signals, effect on avionics, environmental effects, new technology requirements, weight, and cost. Data from Convair's Contract NA 9-10387, Thrust Vector and Aerodynamic Surface Control Actuators, will be utilized.

4. An engine gimbaling system trade study will be conducted to determine the type--hydraulic, pneumatic, or electromechanical--and whether powered from a central power system or from independent engine systems. Evaluate methods for automatic return to locked null at engine or gimbal system failure. Evaluate methods and penalties to provide redundancy required to meet failure criteria. Major selection criteria are weight, performance, space availability, complexity, development time, maintainability, and reusability.

5. Provide FMEA and safety and maintainability analyses.

6. Prepare descriptions of recommended systems, performance data, load profiles, installation concepts, supporting technology requirements, and methods of operation.

WBS Number 3.3.5
Booster Task (Cont)

7.. Provide data for ICD's, CEI specifications, development plans, and reports as required per NASA statement of work.

8. Determine power profile for flight test program requirements. Produce design recommendations to accommodate these requirements.

Company:	Function:	Manager:
GD	Mass Properties	R.L. Benson

9. Determine weight, installed center of gravity, installed moment of interia, material designation, and SP6004 code. Prepare input for digital computer, review design for optimum weight, and establish target weights for weight control.

SPACE SHUTTLE PHASE B
TASK DESCRIPTIONS

WBS TITLE: CREW AND PASSENGER ACCOMMODATIONS (ORBITER)

WBS Number: 2.3.7
Integration Tasks

Company	Function:	Manager:
NR	Flight Technology (Includes Crew Systems)	N.F. Witte

1. Define crew information requirements, crew procedures, work rest cycles, crew and passenger biodynamic and health standards, and habitability requirements to develop design criteria for crew and passenger compartment configuration, windows, lighting, furnishings, personnel support and restraints, cargo handling, flight station controls, displays and panel arrangements, and ingress and egress survival, including nominal and emergency ingress and egress paths, associated crew equipment, survival provisions, and recovery systems. Perform trade studies and evaluations using models, mockups, and human engineering analysis to select optimum personnel accommodations.

2. Provide safety considerations in tradeoff studies influencing crew and passenger accommodations. Document safety assumptions and rationale used. Identify and classify potential and inherent hazards residual in the crew passenger accommodations selected. Provide remedial safety measures for egress and recovery, considering provisions and procedures for nominal and emergency land landings and emergency water landings.

3. Evaluate and document results of the company-sponsored effort as defined below.

   a. Develop "g" envelope parameters during launch, boost, reentry, landing, and ferry flight phases of shuttle vehicles.

   b. Define human biodynamic envelopes considering the $\pm g_{xyz}$ parameters and human response behavior envelopes for operationally preferred, operational maximum, and emergency tolerance limits.

WBS Number 2.3.7
Orbiter Tasks

Company:	Function:	Manager:
NR	Flight Technology	N.F. Witte

4. Conduct the major trade study "integral passenger cabin versus cargo bay personnel module" to determine the optimum design, considering passenger safety and accomodations.

5. Provide and document remedial safety measures for EVA, IVA, and debris and meteoroid protection.

6. Evaluate and document results of the company-sponsored effort as defined below.

   a. Determine general habitability requirements for orbiter missions.

   b. Develop work-space geometry standards using anthropometric analysis and human subject evaluation of mockups. Develop criteria layout drawings.

   c. Determine methods to perform space docking and transfer operations and to provide pre-rescue life support for crew and passengers during various missions. Develop related design requirements.

   d. Investigate external visual field requirements, including FAA and military standards and compare with space shuttle flight requirements to develop design criteria for pilot windows.

   e. Analyze couch/restraint containment system requirements and provide configuration envelopes and dimensional criteria for effective containment. Define optimum couch/restraining configuration options considering crew mobility and vision requirements. Provide criteria and envelope drawings to booster designers to assure commonality.

   f. Compile information on ground emergency egress requirements and prepare study plan to determine ingress/egress system requirements for space shuttle and to evaluate penalties in weight and cost to aid in selection of design criteria.

WBS Number: 2.3.7
Integration Tasks (Cont)

Company:	Function:	Manager:
NR	Crew Technology	A. Moyles

7. Support engineering in the definition of the design/arrangement of the orbiter flight deck by providing operational requirements for crew station stowage, nominal and emergency ingress/egress paths and procedures, optimum arrangement of control and display panel areas, and evaluating external visibility requirements to determine cockpit window configuration and orientation with respect to pilots. Participate in cockpit mockup studies to review, evaluate, and modify the design/arrangement of the flight deck with regard to operational requirements.

8. Support engineering in the design of passenger accommodations in the orbiter by participating in intergral passenger cabin versus cargo bay personnel module trade study, assisting in studies to determine passenger ingress/egress and transfer provisions and procedures and evaluating ECLSS provisions and personnel interfaces.

Company:	Function:	Manager:
NR	Fluids and Propulsion	R. E. Field

9. Finalize baseline life support requirements (breathing-gas supply hardware system weight, volume, power, and configuration) for crew and passengers in support of vehicle configuration and operational analysis.

10. Perform analysis of interior thermal control requirements, including metabolic heat load, cabin heating, and cooling requirements.

11. Determine food preparation equipment and waste management system weight, volume, power, configuration, and supplies.

12. Participate in location of life support equipment and crew and passenger compartment arrangement.

13. Prepare technical documentation and briefings in support of customer and management requirements.

SPACE SHUTTLE PHASE B
TASK DESCRIPTIONS

WBS TITLE: CREW ACCOMMODATIONS

WBS Number: 3.3.6
Booster Tasks

Company:	Function:	Manager:
GD	Power and Fluids	D. Krause

1. Prepare design criteria for controls, seats, etc., required for the manned booster. Adapt crew accommodations criteria from the orbiter where appropriate.

2. Define the windshield configuration and provide vision plots.

3. For the manned booster, support engineering in definition of the design/arrangement of the flight deck by providing operational requirements for nominal and emergency ingress/egress paths and procedures. Participate in cockpit mockup studies to review, evaluate, and modify the design/arrangements of the flight deck with regard to operational requirements. Adapt orbiter flight deck designs and arrangements, where practical.

4. Evaluate and document FMEA and safety and maintainability analyses.

5. Evaluate and document results of company-sponsored studies of:

   a. Controls, seats etc., required for a manned booster for crew support during flight mission operations

   b. Alternate seat configurations considering forces and orientation during vertical and horizontal modes of flight

   c. Alternate configurations and formats of display panels, consoles, flight, throttle controls, including layouts

   d. Location, configuration, and operation of hatches for nominal and emergency ingress and egress considering launch and in-flight operations and water and land landings

SPACE SHUTTLE PHASE B
TASK DESCRIPTIONS

WBS TITLE: LAUNCH SYSTEM INTERFACE

WBS Number: 3.3.7
Integration Tasks

Company:	Function:	Manager:
GD	System Engineering	H. Bonesteel

1. Integrate orbiter data from NR with booster data and prepare and maintain the space shuttle to launch facility ICD, which will document results of the definition performed. The document will contain interface data for structure, power, communication, control, checkout and propellants, and fluids and gases.

WBS Number: 2.3.8	Function:	Manager:
Orbiter Tasks	Operations and Test	W. Edson

2. Define the requirements for the orbiter flight systems interface with ground systems during prelaunch and launch operations.

3. Perform functional analysis and preliminary design to determine the physical, environmental, and procedural interfaces between the orbiter and ground system elements for:

   (1) Servicing

   (2) Purging

   (3) Vehicle umbilicals

   (4) Crew/passenger ingress and egress

   (5) Work platforms

   (6) Jacks and slings

WBS Number: 2.3.8
Orbiter Tasks (Cont)

Company:	Function:	Manager:
NR	Integrated Electronics	G.C. Anderson

4. Support Preliminary Design Engineering in the definition of launch system interfaces of the orbiter through preparation of integrated electronic system interface schematic and preliminary design definition of interfacing integrated electronic system/launch hardware components.

WBS Number: 3.3.7
Booster Tasks

Company:	Function:	Manager:
GD	System Engineering	H. Bonesteel

1. Define the requirements for booster flight systems interface with ground systems during prelaunch and launch operations, including identification of physical connections for structural support and stabilization, power communications, control, checkout, propellants, fluids, and gases.

2. Perform functional analyses and predesign in coordination with NR to define the interface between the flight vehicle and the ground system elements (including, facilities and GSE) for:

   a. Physical (mechanical and electrical)

      (1) Servicing

      (2) Purging

      (3) Vehicle umbilicals

      (4) Crew ingress and egress

      (5) Work platforms

   b. Environmental

   c. Procedural

WBS Number: 3.3.7
Booster Tasks (Cont)

3. Define launch system interfaces of the booster by preparation of integrated electronic system interface schematics and preliminary design definition of interfacing integrated electronic system/launch hardware components.

SPACE SHUTTLE PHASE B
TASK DESCRIPTIONS

WBS TITLE: FLIGHT CONTROL SYSTEMS (FCS)

WBS Number: 2.3.9
Integration Tasks

Company:	Function:	Manager:
NR	Integrated Avionics	G. C. Anderson

1. Support the booster Phase B effort to assure suitability of the flight control system for common usage in orbiter and booster where vehicle/mission requirements are basically identical and for booster unique usage where there is a system difference resulting from unique requirements.

2. Provide technical coordination among GD, IBM, HI, and NR ICD's related to GN&C.

3. Provide technical support to ERB on items related to GN&C baseline.

4. Provide technical coordination with other engineering groups to assure availability of data required for GN&C studies. Submit and control data forwarded to HI.

5. Review and approve HI inputs to the shuttle system specification, orbiter/booster specifications, and the ground system specification.

6. Support other vehicle subsystem groups in accordance with requirements of WBS 1.2.

WBS Number 2.3.9
Orbiter Tasks

Company	Function:	Manager:
NR	Integrated Avionics	G. C. Anderson

7. Define the flight control system requirements in terms of performance and constraints that significantly determine design requirements and constraints on interfacing systems, utilizing data derived from simulation studies (WBS 2.3.9) and analysis (WBS 2.3.2).

8. Provide results from the following company-sponsored simulations to evaluate the flight control system and to evaluate man/machine characteristics and performance during entry, transition, approach, and landing.

   a. Orbital Operations

      (1) Objectives: General study objective is to evaluate ACPS and TVC systems.

         (a) Determine adequacy of ACPS and main engine thrust buildup and decay characteristics and steady-state thrust levels.

         (b) Establish ACPS propellant budgets for attitude control, angular maneuver, and roll control during thrusting maneuver.

         (c) Assess pilot handling qualities.

         (d) Determine ΔV pointing errors resulting from center-of-gravity uncertainty and thrust misalignment.

         (e) Perform FMEA.

      (2) Simulation Configuration

         (a) Six-degree-of-freedom analog

         (b) Fixed base cockpit mockup - external visual scene not required

         (c) Representative controls and displays

WBS Number: 2.3.9
Orbiter Tasks (Cont)

b. Transition and Cruise (straight wing)

(1) Objectives: General study objectives are to provide design data and to perform evaluations of GN&C system designs.

(a) Assess pilot handling qualities of the vehicle, particularly during the pitch-down maneuver.

(b) Determine adequacy of stability augmentation during manual control.

(c) Determine desired altitude for initiation of pitch-down maneuver.

(d) Verify FCS stability margins when body-bending models are included in the mechanization.

(e) Determine requirements for reaction jet control.

(f) Provide design data for determining control surface hinge moments.

(g) Determine subsonic flight characteristics during cruise flight phase.

(2) Simulation Configuration

(a) Six-degree-of-freedom analog

(b) Fixed base cockpit mockup with external visual scene of earth and horizon

(c) Active controls and displays necessary to perform the indicated studies

c. Terminal Phase Rendezvous

(1) Objectives: General study objective is to evaluate final phase rendezvous techniques from approximately 6000 feet relative range to station keeping at approximately 100 feet.

WBS Number: 2.3.9
Orbiter Tasks (Cont)

(a) Determine adequacy of ACPS translational control authority.

(b) Assess pilot handling qualities and work load.

(c) Determine accuracy requirements for range and range data information displayed to the crew.

(d) Establish braking gates ($\Delta V = f(R \& R)$).

(e) Determine ACPS propellant requirements.

(2) Simulation Configuration

(a) Six-degree-of-freedom analog

(b) Fixed base cockpit mockup with external visual scene of a dynamic target vehicle

(c) Active controls and displays required to perform the indicated studies

d. Approach and Landing

(1) Objectives: General study objectives are to assess pilot handling qualities for powered and unpowered approach and landing and to identify required landing aids.

(a) Evaluate pilot handling qualities and workload.

(b) Study AILS and GCA approaches for steep glide slopes associated with unpowered landings.

(c) Evaluate flare, decrab, and rollout maneuvers.

(d) Evaluate go-around capability.

(e) Determine landing loads for all approach and landing concepts evaluated.

(f) Assess vehicle response characteristics.

WBS Number: 2.3.9
Orbiter Tasks (Cont)

(2) Simulation Configuration

(a) Six-degree-of-freedom analog

(b) Fixed-base cockpit mockup with external visual scene of runway and landing field environment

(c) Active controls and displays for required functions

e. Entry

(1) Objectives: General objectives are to evaluate deorbit and atmospheric reentry concepts, with emphasis on pilot handling qualities, corridor control, and targeting.

(a) Perform manual deorbit maneuvers and determine effects of TVC pointing errors and state vector uncertainties on corridor control.

(b) Determine trajectory shaping requirements for both orbiter vehicles (straight and delta wing).

(c) Assess stability and control in transonic flight.

(d) Verify results of the "adaptive versus fixed or scheduled gain" trade study.

(e) Verify reentry guidance concepts.

(f) Establish propellant budgets and determine ACPS duty cycle.

(2) Simulation Configuration

(a) Six-degree-of-freedom hybrid simulation

(b) Fixed base cockpit mockup with external visual scene of earth and horizon

(c) Controls and displays required to perform the indicated functions

WBS Number: 2.3.9
Orbiter Tasks (Cont)

(d) Complete modeling of the aerodynamic characteristics of the vehicle on the digital machine

f. Rendezvous

(1) Objectives: General objective is to perform a closed-loop guidance rendezvous to verify subcontractor rendezvous concepts.

(a) Perform onboard targeting for phasing maneuvers.

(b) Perform required thrusting, e.g., CSI, TPI, MCC's, etc.

(c) Perform state vector updates using manual optics and VHF ranging.

(d) Verify station-keeping concept developed by subcontractor.

(2) Simulation Configuration

(a) Six-degree-of-freedom hybrid

(b) Guidance computer, computer keyboard, and manual sextant included for this study

(c) Fixed base cockpit mockup with external scene of rendezvous target

(d) Controls and displays required to perform the indicated functions

WBS Number: 2.3.9
Orbiter Subcontractor Tasks

Company:	Function:	Manager:
HI	Integrated Avionics	L. Hudson

9. Define flight control system requirements in terms of performance and constraints that significantly determine design requirements and constraints on interfacing systems.

WBS Number 2.3.9
Orbiter Subcontractor Tasks (Cont)

10. Accomplish analysis, definition, preliminary design, and auxiliary studies of the flight control system in terms of control laws, signal shaping, computer requirements, manual participation attitude control and propulsion system requirements, actuator dynamics, and definition of interface requirements on supporting subsystems. Detailed descriptions of HI efforts in support of this WBS are found in WBS 2.3.2.3, Orbiter Subcontractor Tasks.

11. The following simulation activities by HI will serve as an engineering tool for conceptual design and verification of the FCS.

    a. Launch

        (1) Two- and three-degree-of-freedom lateral simulations

        (2) Analog, time varying simulation

    b. Orbit injection

        (Same as a)

    c. On-orbit attitude control

        (1) Three-degree-of-freedom, fixed-point, hybrid simulation

        (2) Digital SCS simulation

    d. On-orbit TVC

        (1) Six-degree-of-freedom, hybrid, fixed-point simulation

        (2) Digital SCS simulation

    e. Low L/D entry

        (1) Six-degree-of-freedom, time-varying, hybrid simulation

        (2) Digital SCS simulation

WBS Number: 2.3.9
Orbiter Subcontractor Tasks

f. High L/D entry

(1) Two-degree-of-freedom pitch, three-degree-of-freedom lateral, fixed-point, analog simulation

(2) Six-degree-of-freedom, fixed-point, hybrid simulation

(3) Analog SCS simulation

WBS Number: 3.3.8
Booster Tasks

Company:	Function:	Manager:
GD	Integrated Avionics	C. E. Grunsky

1. Manage and coordinate the guidance, navigation, and control portion of the HI study that impacts on the booster vehicle. Provide interface information for information acquisition, data display, and guidance and flight controls software.

2. Analyze the attitude-control propulsion system and aerodynamics system and the requirements for the booster flight-control system subsystems and interfaces.

3. Provide basic booster flight-control requirements of response, rates, deflections, and loads for launch portion of flight, up to and including stage separation, entry, transition, cruise, and landing and approach.

4. Define the booster ACPS requirements in terms of thrust, duty cycle, and minimum-impulse bit.

5. Provide design layouts of the booster aerodynamic control surfaces and actuators.

6. The specific results of the studies defined in this task will be documented in an FCS requirements report. Also documented will be results of the following simulations:

   a. Determining separation dynamics for normal staging and abort. A simulation (with each body given six degrees of freedom), complete with plume effects, linkage characteristics, aerodynamics, and control system characteristics will be utilized for this study.

b. Evaluating handling qualities and control characteristics throughout the booster flight profile. A piloted, six-degree-of-freedom, hybrid computer simulation will be performed. The flight control system will be configured using a control analysis program to achieve adequate damping and to minimize cross coupling. Results of the piloted simulation will be in terms of a modified Cooper rating.

c. Analyzing for launch (boost) control system closed-loop stability with propellant sloshing and body bending effects included. A state variable approach program utilized for digital autopilot synthesized initially; then bending and sloshing effects added, and the autopilot modified appropriately.

d. Simulating piloted flights for ferry, approach, and landing phases of flight. The six-degree-of-freedom hybrid simulation with a visual scene of the Cape Kennedy launch facility and runway will be utilized for these evaluations. This simulation will be utilized to evaluate landing in cross winds, the effects and benefits of direct lift devices, etc.

SPACE SHUTTLE PHASE B
TASK DESCRIPTION

WBS TITLE: SEPARATION SYSTEM

WBS Number: 2.3.10
Integration Tasks

Company:	Function:	Manager:
NR	Preliminary Design	W. A. Martin

1. Evaluate candidate separation system concepts and designs in terms of effects to vehicle system (cost, reliability, safety, performance, and recycle). Select best system for final predesign in support of WBS 1.2, System Integration.

WBS Number: 2.3.10
Orbiter Tasks

Company:	Function:	Manager:
NR	Preliminary Design	W. A. Martin

1. Develop and document, in sketches and preliminary design layouts, the provisions in the orbiter vehicles of the space shuttle system for attachment to, and separation from, the booster. The attachment/separation linkage is a part of the booster vehicle.

Company:	Function:	Manager:
NR	Integrated Electronics	G. C. Anderson

2. Support the preparation of the preliminary design of the orbiter attachment and separation provisions by analyzing separation dynamics data and providing requirements for separation mechanics and separation event sequencing.

WBS Number: 3.3.9
Booster Tasks

Company:	Function:	Manager:
GD	Preliminary Design	R. A. Lynch

1. Perform a trade study to evolve a booster/orbiter interconnect and separation system including:

    a. Compare alternative separation systems and recommend a system for predesign based on performance, reliability, safety, cost, and weight.

    b. Provide layouts for final predesign showing geometry, mechanical, and structural provisions. Show pictorial separation history.

    c. Establish detailed sequence of events prior to, during, and after separation for both normal and abort operations.

    d. Evaluate need for auxiliary thrusting during the separation maneuver. Define requirements and hardware type.

Company:	Function:	Manager:
GD	Flight Technology	S. Starr

Assist in the conduct of the separation system trade study including:

2. Perform staging dynamic analyses and loads predictions, including booster-orbiter attach points and loads; and provide separation history, stability, and control analyses.

3. Determine system aeroballistic effects and staging velocity losses.

4. Determine orbiter plume impingement effects on the booster (loads and temperatures).

WBS Number: 3.3.9
Mass Properties

Company:	Function:	Manager:
GD	Mass Properties	R. L. Benson

1. Determine weight, installed cg, installed moment of inertia, material designation, and SP6004 code. Prepare input for digital computer, review design for optimum weight, and establish target weights for weight control.

SPACE SHUTTLE PHASE B
TASK DESCRIPTIONS

WBS TITLE: VEHICLE DESIGN INTEGRATION

WBS Number: 2.4.1
Integration Tasks

Company:	Function:	Manager:
NR	Preliminary Design	W. A. Martin

The method for overall system integration is identified in WBS 1.2

WBS Number: 2.4.1
Orbiter Tasks

Company:	Function:	Manager:
NR	Preliminary Design	W. A. Martin

Perform the orbiter vehicle/subsystem design integration tasks of the space shuttle system required to:

1. Integrate all baseline subsystems within both baseline orbiters such that overall aerodynamic configurations and primary structure concepts are maintained, at the same time assuring that the desired subsystem requirements are provided.

2. Participate in the system evaluation/selection process relative to trade studies to define subsystems to be integrated into the orbiter vehicles.

3. Document the preliminary designs of the orbiter configurations for submittal to NASA.

4. Evaluate and document the results of the company sponsored study to develop methods of parametric and preliminary design synthesis.

5. Evaluate and document the results of the company sponsored trade studies and design studies for the impact of their changes on the external and internal configuration and subsystems of the orbiters.

Company:	Function:	Manager:
NR	System Engineering	J. Bates

6. Review subsystem descriptions (schematic block diagrams) to develop integrated schematic block diagram for the orbiter vehicle.

WBS Number: 2.4.1
Orbiter Tasks (Cont)

7. Document results of design integration task in appropriate sections of Systems Definition Handbook to reflect a current configuration of the orbiter vehicle and related subsystems.

Company:	Function:	Manager:
NR	Fluids and Propulsion	R. E. Field

8. Furnish descriptions and data on alternate approaches to design of power systems to include functional descriptions, operating characteristics, interfaces with other systems, size and weight characteristics for individual elements, and preferred location of individual elements, accessibility requirements, and environmental restrictions.

Company:	Function:	Manager:
NR	Project Engineering	G.F. Fraser

9. Review design integration task approach and schedule for data exchange between groups.

10. Through direction and coordination among functional groups, assure compatibility between orbiter and subsystems and development of orbiter vehicle arrangement.

11. In company sponsored activities direct development of shuttle design synthesis programs.

WBS Number: 3.4.1
Booster Tasks

Company:	Function:	Manager:
GD	Preliminary Design	R.A. Lynch

Integrate the design of the booster vehicle. Perform design analyses to evaluate the compatibility of subsystems and of the booster with the orbiter. Prepare design layouts to establish spatial relationships of booster hardware and assemblies.

1. Identify and define the booster external configurations, major elements, internal arrangements, subsystems, geometry, mass properties, and performance.

WSB Number: 3.4.1
Booster Tasks (Cont)

2. Evaluate the impact of changes in the external and internal configuration elements and subsystems on the booster vehicle and provide these data to NR to establish the effect on the overall space shuttle system.

3. Support NR inevaluating the effect of booster alternate approaches on the overall system. Assist NR in making configuration selections.

4. Maintain a detailed history and comparison of the booster configurations, the alternatives and the selections made with traceability to trade study and design analyses to substantiate the choices.

5. Establish the final predesign booster requirements.

6. Synthesize and configure the final preliminary design booster compatible with the NR selected space shuttle system.

SPACE SHUTTLE PHASE B
TASK DESCRIPTIONS

WBS TITLE: PRELIMINARY DESIGN DRAWINGS

WBS Number: 2.4.2
Integration Tasks

Company:	Function:	Manager:
NR	Preliminary Design	W.A. Martin

1. Coordinate drawing preparation to assure a common coordinate system for the identification of stations and waterlines.

2. Prepare mated vehicle preliminary design drawings showing general arrangement and dimensions.

WBS Number: 2.4.2
Orbiter Tasks

Company:	Function:	Manager:
NR	Preliminary Design	W.A. Martin

Prepare overall orbiter vehicle (high cross-range and low cross-range vehicles) preliminary design drawings in accordance with the NR Drawing Requirements Manual (DRM) and MIL-D-1000, Form 2, Category A, using NR drawing numbers and code identification numbers, including the following:

1. General arrangement of each orbiter (1/100 scale), showing plan, side, front, and/or aft views; dimensional data, major component arrangement and center-of-gravity locations.

2. Inboard profile of each orbiter (1/50 scale), showing side view and cross sections to identify size and location of major subsystems, such as crew, passengers, cargo, propulsion systems, environmental control and life support systems and mechanical systems.

3. General arrangement drawings (1/50 scale) of major subsystems to identify component location and relative structural elements.

4. Prepare separate drawings for the two orbiter vehicles of the crew/passenger compartment; alternate passenger pallet; cargo compartment, including handling system; docking and crew/cargo transfer system; main propulsion system installation; auxiliary propulsion system installation; attitude control system installation; cruise propulsion system installation; environmental and life support installation; integrated avionics

WBS Number: 2.4.2
Orbiter Tasks (Cont)

installation; power generating systems installation; mechanical landing system installation; and docking system installation.

5. Orbiter three view.

6. Orbiter external lines.

Company:	Function:	Manager:
NR	Fluids and Propulsion	R. E. Field

7. Prepare attitude control propulsion system (ACPS) component detail descriptions and physical characteristics plus unique installation requirements in support of Preliminary Design.

8. Conduct booster/orbiter commonality investigation. Coordinate study activity with Convair Propulsion group and component vendors.

9. Support System Safety by inclusion of system safety considerations in the propulsion system definition tradeoff analyses, including propulsion system, propellant loading, fuel and utilization system, and the pneumatic systems. Document the safety assumptions and rationale used in reaching tradeoff decisions and recommendations. Identify and document on hazard analysis sheets the residual hazards in the propulsion system affecting the booster, orbiter, personnel, and facilities and describe the hazards in detail.

10. Provide inputs in support of the failure modes effects analysis effort for the ACPS.

11. Provide details of all components of the engine, engine installation, fuel system, and allied propulsion subsystems for interim air-breathing propulsion design drawings. Update and refine propulsion details for preliminary design definition and drawing.

12. Provide engine and system design concepts, sizes, and configuration of all significant subsystem components to support vehicle arrangement, inboard profiles, and detailed subsystem-installation-type drawings for main propulsion.

WBS Number: 3.4.2
Booster Tasks

Company:	Function:	Manager:
GD	Preliminary Design	R.A. Lynch

1. Prepare overall booster vehicle preliminary drawings in accordance with MIL-D-1000, Form 2, Category A, using GD drawing numbers and code identification numbers including the following:

   a. Booster general arrangement (1/100 scale), showing plan, side, front, and aft views; dimensional data; and major component arrangement. Booster center of gravity will be included.

   b. Booster external loft lines.

   c. Booster exterior three view.

   d. Booster inboard profile (1/50 scale). Side view and sections with component key identifying all significant subsystem components.

   e. Layout of booster/orbiter interconnect and separation system.

Company:	Function:	Manager:
GD	Propulsion	A. Schuler

2. Prepare propulsion system preliminary drawings in support of overall booster preliminary design including:

   a. Flyback propulsion engine installation and fuel system.

   b. Main rocket propulsion installation.

   c. Propellant feed and pressurization installation and schematic.

   d. Reaction control system installation and schematic.

Company:	Function:	Manager:
GD	Subsystems	D. Krause

3. Prepare subsystem preliminary drawings in support of overall booster preliminary design including:

   a. Nose and main landing gear installation and system schematics.

   b. Flight deck arrangement including visibility diagrams.

WBS Number: 3.4.2
Booster Tasks (Cont)

c. Flight control system installation and schematic.

d. Power generation system installation and schematic.

e. Environmental control system installation and schematic.

Company:	Function:	Manager:
GD	Structure and TPS	F. Krohn

4. Prepare structure and TPS preliminary drawings in support of overall booster preliminary design including layouts of:

   a. Overall structure general arrangement.

   b. Forebody structure.

   c. Main LO_2 tank structure.

   d. Thrust structure and launch support structure.

   e. Intertank structure.

   f. Main LH_2 tank structure and insulation.

   g. Aft body structure.

   h. Overall TPS arrangement.

   i. Wing and wing carry-through structure.

   j. Empennage and carry-through structure.

Company:	Function:	Manager:
GD	Ground Support Equipment	M. Stone

5. Prepare GSE and facilities drawings in support of the overall shuttle system preliminary design definition.

Company:	Function:	Manager:
GD	Integrated Electronics	C. Grunsky

6. Prepare booster integrated installation drawings (including antennas) and schematics in support of overall shuttle system preliminary design.

SPACE SHUTTLE PHASE B
TASK DESCRIPTIONS

WBS TITLE: MOCKUP AND MODELS

WBS Number: 2.4.3
Integration Tasks

Company:	Function:	Manager:
NR	Preliminary Design	W.A. Martin

1. Coordinate design and fabrication of NR and GD mockup of the flight deck area to assure commonality of controls and displays where applicable.

2. The method for overall system integration is defined in WBS 1.2.

WBS Number: 2.4.3
Orbiter Tasks

Company:	Function:	Manager:
NR	Preliminary Design	W.A. Martin

1. Prepare drawings for the fabrication of full-scale, soft mockup of the crew/passenger compartment of selected orbiter vehicle. Drawings to be sufficient detail to define major structural members; controls and displays, including crew seating and visibility; passenger accommodations and location and identification of personnel equipment.

2. Conduct NASA review of mockup and make approved revisions.

3. Prepare drawings for fabrication of 1/96 scale models of orbiter vehicles.

Company:	Function:	Manager:
NR	Flight Technology	N.F. Witte

4. Provide design requirements for soft mockup development to assure compatibility with crew operation evaluations, measurement and photography, human subject safety, and spacesuit support equipment procedures.

WBS Number: 2.4.3
Orbiter Tasks (Cont)

5. Evaluate and document the results of the related company-sponsored effort described as follows:

   a. Investigate use of soft mockup of crew and passenger station workspace to determine optimum crew workspace geometry.

   b. Develop techniques for small-scale modeling of crew and passenger accommodation arrangements using foam core and papers. Prepare sample table top mockup.

Company:	Function:	Manager:
NR	Manufacturing	J.W. Cuzzupoli

6. Fabricate and assemble full-scale, soft mockup of the selected orbiter flight deck and passenger compartment. The compartment will be of sufficient detail to enable Manufacturing to verify vehicle breakdown plans, handling, tooling, and component details and sizes. In addition, provide a mockup which will be utilized to determine assembly and installation sequences. Fabricate and assemble 1/96 scale models of the external configuration of the orbiter.

WBS Number: 3.4.3
Booster Tasks

Company:	Function:	Manager:
GD	Preliminary Design	R.A. Lynch

1. Design full-scale, soft mockup. Mockup to be flight deck area. Coordinate mockup construction and utilization.

2. Conduct NASA reviews of mockups and make necessary revisions.

3. Prepare designs for 1:96 scale models of booster.

Company:	Function:	Manager:
GD/C	Manufacturing	D. Fagan

4. Fabricate full-scale crew compartment mockup and models. The fabrication of models and assembly of models will be of sufficient detail to enable Manufacturing to verify vehicle breakdown plans, handling, tooling, and component details and sizes. Fabricate and assemble 1/96 scale models of external configuration of the booster.

SPACE SHUTTLE PHASE B
TASK DESCRIPTIONS

WBS TITLE: INTERFACE DEFINITION AND CONTROL DOCUMENTATION

WBS Number: 2.4.4
Integration Tasks

Company:	Function:	Manager:
NR	System Engineering	J. Bates

1. Coordinate preparation of preliminary interface control documents (ICD's) listed below, in accordance with NASA Data Requirements Description (DRD) CM009M, dated 22 May 1970. Identify requirements, format, and responsibility for ICD's. Integrate and approve requirements and changes provided by subcontractors. Maintain control of ICD's after approval by NASA. Identify need for ICD's to be developed for Phase C/D. Planned ICD's are as follows:

    Booster/orbiter
    Orbiter/space station
    Orbiter/payload module
    Booster/orbiter/main rocket engine
    Shuttle vehicle/launch facility
    Orbiter/booster/M&R

WBS Number: 2.4.4
Orbiter Tasks

Company:	Function:	Manager:
NR	Preliminary Design	W. Martin

1. Provide technical data for, and participate in, the negotiation of the technical interfaces of the orbiter vehicle of the Space Shuttle System.

WBS Number: 2.4.4
Orbiter Tasks (Cont)

2. Provide support to System Engineering for the preparation of ICD's by preparing drawings documenting pictorially and dimensionally the interfaces of the following items:

   Booster/orbiter
   Orbiter/space station
   Orbiter/payload module
   Orbiter/main rocket engine
   Orbiter/launch facility
   Orbiter/M&R

WBS Number: 3.4.4
Booster Tasks

Company:	Function:	Manager:
NR	Systems Integration	H. Bonesteel

1. Provide technical data, support to NR and prepare ICD's of the booster vehicle for the Space Shuttle System. Coordinate, determine effects of, and provide control of changes to ICD's. Assist in identification of need for ICD's for Phase C/D. Prepare support preparation of the following:

   Booster/orbiter
   Booster/launch facility
   Booster/main rocket engine
   Booster/M&R

SPACE SHUTTLE PHASE B
TASK DESCRIPTIONS

WBS TITLE: SPECIFICATIONS

WBS Number: 2.4.5
Integration Tasks

Company:	Function:	Manager:
NR	System Engineering	J. Bates

Coordinate and integrate data developed through requirements analysis tasks under WBS 2.1.2. Ensure the proper allocation of requirements from the system level to identifiable end items. Review, approve, submit to NASA, and coordinate changes of the Orbiter and Booster Preliminary Development Specifications (CEI - Part I) and the Shuttle Preliminary System Specification.

WBS Number: 2.4.5
Orbiter Tasks

Company:	Function:	Manager:
NR GD	System Engineering	J. Bates

Prepare and publish the Preliminary Orbiter Vehicle Development Specification (CEI - Part I), per NASA DRD CM007M. Coordinate changes, revise, and prepare document for final submittal.

WBS Number: 3.4.5
Booster Tasks

Company:	Function:	Manager:
	System Engineering	H. Bonesteel

1. Define booster vehicle specification requirements and group equipment specification requirements.

2. Prepare Preliminary Booster Vehicle Development Specification per DRD CM007M.

WBS Number: 3.4.5
Booster Tasks (Cont)

3. Prepare Preliminary Ground Systems General Specification.

4. Revise and update these specifications as required and submit to NR for review and approval.

SPACE SHUTTLE PHASE B
TASK DESCRIPTIONS

WBS TITLE: SUPPORTING RESEARCH AND TECHNOLOGY

WBS Number: 2.5
Integration Tasks

Company:	Function:	Manager:
NR	Shuttle Technology	L.A. Harris

1. Develop criteria and format for selecting and recording technology development items and for establishing needs and requests for technology data.

2. Integrate booster and orbiter SRT items and coordinate with customer. Publish SRT report and quarterly updates in accordance with DRD MA 022M.

3. Coordinate and integrate GD and NR quarterly summary reports on independent research and development for transmittal to customer.

WBS Number: 2.5
Orbiter Tasks

Company:	Function:	Manager:
NR	Shuttle Technology	L.A. Harris

1. Identify supporting research and technology requirements critical or pacing to design. Assist in defining schedule cost and risk impact on technology development.

2. Prepare quarterly letter report summarizing the NR independent research and development related to shuttle. Present the program objectives, technical approach, task descriptions and significant results.

WBS Number: 3.5
Booster Tasks

Company:	Function:	Manager:
GD		R.A. Nau

1. Conduct effort for the identification of items of technology critical or pacing to design and prepare a statement of need for technology data.

2. Conduct research to provide a letter report summarizing GD independent research and development related to space shuttle on quarterly basis. The reports will include a concise justification for the inclusion of the particular technology item and describe the program objective, statement of problem, technical approach, and task description. It will also include a milestone schedule with costs that are directly related to the space shuttle Phases B and C/D milestones.

SPACE SHUTTLE PHASE B
TASK DESCRIPTIONS

WBS TITLE: PROGRAM PLANNING AND CONTROL

WBS Number: 4.1
Integration Tasks

Company:	Function:	Manager:
NR	Program Planning and Control (Business Operations)	S. L. Weinberg

1. Develop and maintain shuttle Phase B work breakdown structure.

2. Develop and maintain shuttle Phase B integrated program summary schedules.

3. Develop and maintain Phase B Shuttle Program logic network and conduct PERT/schedule analyses; develop alternative schedule plans as required.

4. Provide management visibility and Shuttle Program progress/status.

5. Develop and maintain Phase C/D Shuttle Program WBS, master schedule, and logic networks as inputs to Phase C/D acquisition plans.

WBS Number: 2.6.1
Orbiter Tasks

Company:	Function:	Manager:
NR	Program Planning and Control (Business Operations)	S. L. Weinberg

1. Develop and maintain orbiter work breakdown structure (WBS).

2. Develop and maintain orbiter master program schedule.

3. Develop and maintain orbiter logic network; conduct PERT and schedule analyses and develop alternative schedule plans as required.

4. Provide orbiter management visibility and progress and status.

WBS Number: 2.6.1
Orbiter Tasks (Cont)

5. Develop and maintain baseline Phase C/D orbiter program logic network, master schedule, and WBS.

6. Associate Contract Administration is responsible for the overall administration and integration of Convair Phase B effort. This effort will include the negotiation, award, and continuing administration of an associate contract with the Convair Division of General Dynamics Corporation, which will entail the following administration subtasks:

   a. Negotiate associate contract Statement of Work, data requirements and other terms and conditions.

   b. Award associate contract.

   c. Ensure that schedule and technical goals are met.

   d. Coordinate program/project reviews of Convair performance.

   e. Monitor milestone accomplishment.

WBS Number: 3.6.1
Booster Tasks

Company:	Function:	Manager:
GD		G.E. Putness

1. Coordination with responsible project functions and preparation of GD input to the monthly project progress and status report (DRD MA020M).

2. Maintenance of the GD portion of Phase B work breakdown structure (WBS) networks and schedules.

3. Administrative control and direction for Phase B WBS element and work package task descriptions.

4. Administrative control of the space shuttle program control room.

5. Correlation and validation of input data and output reports of the ETSR system to Phase B networks and schedules.

6. Preparation of recommendations for corrective action when actual or potential cost or schedule variations are detected.

SPACE SHUTTLE PHASE B
TASK DESCRIPTIONS

WBS TITLE: DOCUMENTATION MANAGEMENT

WBS Number: 4.2
Integration Tasks

Company:	Function:	Manager:
NR	Program Contract Performance (Business Operations)	S. L. Weinberg

Provide a documentation management system affording the controls and discipline necessary for effective management of the Phase B documentation effort. Assure effective development and control of contractually deliverable, internal, and subcontractor data. Perform integration activities which assure compliance to document content, format, schedule and distribution requirements. Perform planning applicable to Phase C/D documentation development. Provide Publications support for the preparation of selected Phase B contract deliverable documentation.

Subtasks

1. Deliverable Documentation Management

    a. Identify and define in detail the contractually deliverable data items specified in the Data Requirements Descriptions (DRD), NASA Form 9.

    b. Control, monitor, and assure continuity of efforts during the development and preparation of documentation.

    c. Provide documentation schedule and performance visibility for Program Management.

    d. Provide for the release, reproduction, packaging, and shipment of deliverable documentation.

    e. Develop Phase C/D administrative documentation criteria and prepare planning requirements.

WBS Number: 4.2
Integration Tasks

2. Subcontractor Documentation Management

   a. Identify subcontractor/associate contractor documentation requirements and criteria. Prepare descriptions defining documentation format, content, and delivery schedules.

   b. Assist in fact findings/negotiations of subcontractor/associate contractor documentation requirements.

   c. Perform continued analysis of program versus subcontractor/associate contractor documentation schedules to verify compatibility.

   d. Receive data shipments, process, and obtain reviews and approvals. Monitor subcontractor/associate contractor data performance and provide management visibility.

   e. Develop documentation rationale for subcontractor/associate contractor requirements during Phase C/D.

3. Publications

   Provide writing, editing, illustrating, typing, and production support during preparation of final deliverable documentation.

WBS Number: 2.6.2
Orbiter Tasks

Company:	Function:	Manager:
NR	Program Contract Performance (Business Operations)	S. L. Weinberg

Provide a documentation management system affording the controls and discipline necessary for effective management of the Phase B orbiter documentation effort. Assure effective development and control of orbiter input data required for the integrated set of program end item documentation. Perform integration activities which assure compliance to document content, format, and schedule requirements.

Manpower included in WBS 4.2.

WBS Number: 4.3
Booster Tasks (Cont)

Company:	Function:	Manager:
GD		G.E. Putness

1. Perform analyses of data requirements in order to define and develop the format and content of the documentation to be provided during the course of Phase B.

2. Finalize DRD's and data coordination tasks with NR Data Management.

3. Monitor data preparation and submittal status to ensure on-time data submittals.

4. Review technical data outputs to ensure continuing applicability of data in accordance with NR requirements.

5. Prepare Phase C Data Management Plan as input to the Program Management Plan.

SPACE SHUTTLE PHASE B
TASK DESCRIPTIONS

WBS TITLE: CONFIGURATION MANAGEMENT

WBS Number: 4.3
Integration Tasks

Company:	Function:	Manager:
NR	Quality Assurance	L. B. Gray

Integrate and institute compatible configuration management approaches and disciplines for the space shuttle orbiter and booster. This task includes:

1. Development of policies and defining attendant procedures.

2. Establishment of an integrated system for baselining program configuration critical documents and providing control of changes thereto.

WBS Number: 2.6.3
Orbiter Tasks

Perform the following configuration management activities for the orbiter:

1. Establish a system to control and maintain an accounting of all baselined configuration documents and changes thereto.

2. Establish a system to control assignment of all configuration identification numbers.

3. Act as interface and focal point for NR on configuration management matters pertaining to the orbiter. This includes coordination with NASA, Convair, subcontractors, vendors, and within NR.

4. Prepare, as a company-sponsored activity, a preliminary draft configuration management requirements plan to identify the requirements for the conduct of Phase C/D.

5. Support and assist Engineering in the development of specifications, specification trees, interface control drawings, and associated index listings.

WBS Number: 3.6.3
Booster Tasks

Perform the following configuration management activities for the booster:

1. Release and record the program requirements baseline configuration identification (SDH Volume 1, Part II and Part IV).

2. Assign and control all configuration identification numbers.

3. Release and record changes to the initial baseline configuration (SDH Volume II, Part I and Part IV).

4. Act as the focal point for Convair on all configuration management matters pertaining to the space shuttle. This includes coordination with NASA, NR, subcontractors, vendors, and within Convair.

SPACE SHUTTLE PHASE B
TASK DESCRIPTIONS

WBS TITLE: REPORTS/REVIEWS COORDINATION

WBS Number: 4.4
Integration Tasks

Company:	Function:	Manager:
NR	Program Planning and Control	S. L. Weinberg

Integrate NR and GD inputs for special NASA reviews and evaluations, working sessions, internal reviews, and special conferences with NASA at times and places to be determined, including monthly program status reviews and progress reports.

WBS Number: 2.6.4
Orbiter Tasks

Company:	Function:	Manager:
NR	Program Planning and Control (Business Operations)	S. L. Weinberg

Collect, edit and compile in support of contract requirements, data for informal and formal reports and reviews with NASA. This includes special working sessions, internal reviews, and special conferences with NASA at times and places to be determined.

Subtask - Program Reviews and Presentations

Collect documents for review and reference.

Prepare viewgraphs, charts, and briefing materials.

Publish minutes and action-item listings.

Provide copies of presentation material for NASA as required.

Provide progress summary for monthly progress reports.

WBS Number: 3.6.4
Booster Tasks

Company:	Function:	Manager:
GD		G. E. Putness

1. Participate in accumulation of technical summary report information for assimilation and coordination with NR.

2. Participate in accumulation of executive summary report information as to descriptive data on definitive booster configuration data.

3. Participate in accumulation of final report information, including considerations of booster configuration, systems engineering documentation, tradeoff study conclusions, technical considerations pertinent to selection of proposed configurations.

SPACE SHUTTLE PHASE B
TASK DESCRIPTIONS

WBS TITLE: PROGRAM MANAGEMENT PLAN

WBS Number: 4.5.1
Integration Tasks

Company:	Function:	Manager:
NR	Business Operations	S. L. Weinberg

Define contents of a Program Management Plan which identifies the requirements for managing a Phase C/D Shuttle Contract (either orbiter or booster). Assign NR and GD preparation responsibilities for each section, develop detail review and input schedules, prepare NR/GD plan of action to initiate effort, administer plan preparations, and integrate for delivery to NASA.

WBS Number: 4.5.1
Orbiter Tasks

Company:	Function:	Manager:
NR	Program Planning and Control	S. L. Weinberg

Prepare a plan to define the management concept and approach for the Phase C/D Orbiter Program. The plan will contain the information specified in DRD MAO17M and will stress the cost saving techniques to be implemented by a contractor in accomplishing the design, development, fabrication, and development testing of the total shuttle system.

The method for developing the management data will be through an analytical evaluation of current business management systems. Early in Phase B, the major effort will be to identify management areas where significant cost reductions might be achieved. This will be accomplished through a continual examination of existing systems for cost reducing simplifications or improvements. The culmination of this evaluation process will be a formal management review to approve recommended cost reduction changes in management systems. This formal review which occurs on each of the program acquisition plans is also referred to as the "Management Procedures Evaluation Trade Study."

WBS Number: 4.5.1
Orbiter Tasks (Cont)

Company:	Function:	Manager:
NR	System Engineering	J. Bates

1. Provide engineering support to the preparation of the Program Management Plan. Participate in the establishment of Phase C/D WBS, schedules, and test program flows.

2. Evaluate Engineering management procedures in support of the Management Procedures Evaluation Trade Study.

   a. Analyze engineering product flow and procedures to establish a simple minimum cost system in the areas of change control and engineering release system.

   b. Develop plans for maintaining drawing tree and indentured parts list consistent with manufacturing flows to minimize manufacturing paperwork.

Company:	Function:	Manager:
NR	Configuration Management (Q&RA)	L. B. Gray

Analyze Phase C/D configuration management requirements and prepare configuration management section of the Program Management Plan.

WBS Number: 4.5.1
Booster Tasks

Company:	Function:	Manager:
GD		G. E. Putness

Support SD in the preparation of an integrated management plan through identifying cost reducing adjustments in existing management systems. Obtain formal GD Management approval of management system adjustments and input to SD for integration into the plan. Support SD in fulfilling all other requirements of DRD MA017M.

SPACE SHUTTLE PHASE B
TASK DESCRIPTIONS

WBS TITLE: ENGINEERING DEVELOPMENT PLAN

WBS Number: 4.5.2
Integration Tasks

Company:	Function:	Manager:
NR	System Engineering	J. Bates

1. Prepare outline of plan which includes system performance monitoring, design verification process, indification of interfaces, integration of design and system performance, analysis and evaluation of development tests, engineering procedures, and engineering product flow. Coordinate outline and content with NASA.

2. Monitor results of engineering review process to insure that design and development costs are minimized in design studies. This effort is part of WBS 2.1.1 and 3.1.1.

3. In conjunction with WBS 4.5.5, develop methodology to reduce development and qualification test cost. This will involve the formulation of a verification program guidelines document and test network.

4. As part of the management procedures evaluation trade study of WBS 4.5.1, analyze methods to simplify engineering procedures in the areas of change control, drawing release and updating, engineering order accounting system, etc.

5. Based on WBS 4.5.5 tasks, evaluate methods to reduce checkout procedures and their associated paperwork.

6. Establish procedures to identify interfaces in conjunction with WBS 2.1.1, 2.4.4, and 3.4.4.

7. Define the analysis and evaluation procedures of development test data.

8. Evaluate a technical performance tracking procedure to monitor the vehicle system performance.

9. Prepare rough draft of plan at sixth month.

WBS Number: 4.5.2
Integration Tasks (Cont)

10. Prepare complete preliminary draft of plan at seventh month and submit to NASA at eighth month.

11. Based on NASA comments, prepare final plan.

WBS Number: 4.5.2
Orbiter Tasks

Company:	Function:	Manager:
NR	System Engineering	J. Bates

1. In conjunction with WBS 2.1.1 and 4.5.5, monitor the formulation of the orbiter development and qualification test requirements.

2. As part of WBS 2.1.1, monitor design and development approach to ensure cost is minimized by participation in engineering review decisions.

3. Based on Space Division manuals, develop the engineering method and procedures applicable to orbiter. These will minimize and simplify the procedures and documents, yet assure adequate control and traceability. The areas to be covered include: change control, interface/ICD control, test monitoring and control, product planning, drawing system, and drawing release.

4. In conjunction with Integration Task 8, establish a technical performance tracking system applicable to the orbiter.

5. Prepare drafts of the orbiter portions of the plan.

WBS Number: 4.5.2
Booster Tasks

Company:	Function:	Manager:
GD	System Engineering	L. Munson

1. Participate in ERB to monitor design and development costs as part of the review process.

WBS Number: 4.5.2
Booster Tasks (Cont)

2. Monitor, as part of WBS 3.1.1 and 4.5.5, the booster development and qualification test requirements.

3. Generate a technical performance tracking system applicable to the booster in conjunction with Integration Task 8.

4. Develop engineering procedures for the booster which will provide adequate simple document/control and traceability.

5. Prepare drafts of the booster portions of the plan.

SPACE SHUTTLE PHASE B
TASK DESCRIPTIONS

WBS TITLE: OPERATION PLAN

WBS Number: 4.5.3
Integration Tasks

Company:	Function:	Manager:
NR	Operations and Test	W. Edson

1. Prepare outline of operations plan which includes mission operations, post-flight operations, prelaunch operations, and ferry operations. Coordinate outline and content with NASA.

2. Based on functional flow analyses data generated in WBS 2.1.3 and 3.1.3, prepare first draft of the plan which includes top level operations requirements.

3. Generate a methodology to assemble, assess and use development, qualification and operational data in establishing operational methods and limitations of the shuttle.

4. Perform a study to reduce operating costs and simplify operation procedures. This task will also use the results of these analyses as a minimum: self-ferry trade study WBS 2.1.10 and 3.1.10; operations site evaluation trade study WBS 2.1.3 and 3.1.3; vehicle abort capability trade study WBS 2.1.7 and 3.1.7; and management procedures evaluation trade study WBS 4.5.1, plus other design analyses such as maintenance flight profiles, etc. This study will include analysis of present Apollo operational procedures, airline operations, and recommend best procedures.

5. Generate revised operations plan to support major NASA reviews at three, six months. This will be accomplished by use of results of Task 4 and associated trade studies and analyses as well as detailed functional analysis and requirements definition of WBS 2.1.1, 3.1.1, 2.1.3 and 3.1.3.

6. Prepare preliminary draft of plan for submittal to NASA at eighth month.

7. Based on NASA comments, prepare final plan.

WBS Number: 4.5.3
Integration Tasks (Cont)

8. Based on results of orbiter self-ferry trade study WBS 2.1.10, document the self-ferry operations requirements.

9. Based on results of WBS 2.1.11 (ground/flight optimization), 4.5.5 (test planning), 2.1.3 (operations analysis), and the subsystem tasks, describe the operational flow of the orbiter during storage, checkout, maintenance, and servicing and safing.

10. Develop the operational interfaces and equipment descriptions using the analyses of WBS 2.1.2 and 2.3.8.

11. Incorporate the timeline analyses of WBS 2.1.2 to provide description of flight events to the level necessary for use in planning and flights.

12. Develop optimized flight modes descriptions including docking, cargo transfer, landing using the analyses of WBS 2.1.5 and 2.1.12.

13. Using results of subsystem studies, develop and document the mission duty cycles and the flight constraints including contingency rules, decision intervals and critical environments.

WBS Number: 4.5.3
Booster Tasks

Company:	Function:	Manager:
GD	Operations	P. M. Prophett

1. Using results of self-ferry trade study WBS 3.1.10, document the booster self-ferry requirements.

2. Describe the operational flow of the booster including safing, storage, maintenance, checkout, and servicing using the analyses of WBS 3.1.3 operations analysis, 4.5.5 test planning, 3.1.11 - ground/flight optimization, and the subsystem tasks.

3. Describe the flight event including subsystem duty cycles and constraints-contingency rules, decision times and critical environments.

4. Incorporate the timeline analysis of WBS 3.1.2.

SPACE SHUTTLE PHASE B
TASK DESCRIPTIONS

WBS TITLE: FACILITIES UTILIZATION AND MANUFACTURING PLAN

WBS Number: 4.5.4
Integration Tasks

Company:	Function:	Manager:
NR	Manufacturing and Facilities	J. W. Cuzzupoli

Coordinate facilities planning and data exchange between NR and GD/C in order to optimize facilities utilization, avoid facilities duplications, and minimize total cost. Coordinate the conduct of mutually beneficial facility trade studies, transportation analysis, and other commonality facility studies and analyses. Develop information exchange to ensure compatibility of facilities plan development and coordinate integration of facilities plans. Coordinate and exchange data between NR and GD/C, in order to obtain maximum utilization and minimize costs, for items such as hardware assembly flow logics, assembly breakdowns, tooling, testing concepts, producibility considerations, other hardware and related cost/schedule control systems.

WBS Number: 4.5.4
Orbiter Tasks

Company:	Function:	Manager:
NR	Manufacturing and Facilities	J. W. Cuzzupoli

1. Manufacturing will evaluate production requirements and identify major problems anticipated. Problem identification will be based on assessment of technology requirements, producibility considerations, tooling requirements, testing requirements and concepts, and schedules and cost limitations. Additionally, basic manufacturing assembly breakdowns, tooling/testing concepts, preliminary master schedules, production control systems and planning concepts will be definitized and documented during the Phase B study.

2. Problems will be evaluated and solutions developed which present the optimum manufacturing approach. Proposed solutions will define

WBS Number: 4.5.4
Orbiter Tasks (Cont)

required manufacturing technologies and processes and identify those technologies and processes and identify those technologies and techniques which require advancement of the state-of-the-art.

3. Manufacturing requirements for Government-furnished major machine and fabrication tools will be identified and defined to specific manufacturing operation.

4. The plans and all pertinent supporting data will be submitted to NASA for inclusion in Facility Utilization and Manufacturing Plan (TM001M).

5. Manufacturing requirements for Government-furnished special major test equipment will be identified and defined by description, use, estimated cost, and location.

6. Determine requirements for major new facilities and utilization of existing major facilities for development, test, manufacture, and operations of the orbiter vehicle. These requirements will be defined to include identification of floor space, environment, power services, special handling capabilities, and desired location. Requirements for major new facilities will be justified by analytical trade studies and cost optimizations. Proposed usage of existing Government-owned facilities will be accompanied with a statement of acceptability of joint use or work-around situations, when facility man-loading factors so indicate. Requirements for procurement of long-lead time facilities will be identified.

Company:	Function:	Manager:
NR	Systems Engineering	J. Bates

7. Define the design requirements for operational facilities as required to support manufacturing trade studies associated with those facilities. Support Manufacturing Test Engineering, as required, with definition design requirements for orbiter vehicle systems and ground support equipment; support to include definition of vehicle systems checkout requirements and specific specifications associated with those systems. Support final preparation of a Facilities Utilization and Manufacturing Plan.

WBS Number: 4.5.4
Orbiter Tasks (Cont)

Company:	Function:	Manager:
NR	Operations and Test	W. Edson

8. In support of the preparation of the Facility Utilization and Manufacturing Plan, provide the Test and Operations effort required to define preliminary facility requirements relating to test and provide initial estimates of the test facility need dates and vehicle test and support equipment installation and checkout schedules.

WBS Number: 4.5.4
Booster Tasks

Company:	Function:	Manager:
GD/C	Manufacturing	D. L. Fagan

1. The plan will specify and define major facilities and equipment required for manufacturing, development testing, and ground and flight testing of the booster and prelaunch, launch, and ground operations for the integrated system. The plan will identify the requirements for government and contractor-operated facilities, including modifications/additions, new construction, floor space, environment, power, services, and special handling capabilities. Items of work include:

   a. Based on the facility requirements generated under Tasks 4.1, 4.2, 4.3, and the baseline configuration, facility study plans will be developed. Key considerations will be maximum use of existing manufacturing, development testing, flight testing, launch, and operation capabilities. Subsystem and integrated system tradeoff studies, analytical evaluation, and overall program schedule and cost analyses will be performed to achieve the facility implementing approach.

   b. Long lead-time facilities/equipment and special test equipment requirements will be identified.

   c. New construction or major modification to existing facilities will be justified by analytical studies with all pertinent supporting data submitted to NASA.

WBS Number: 4.5.4
Booster Tasks (Cont)

2. Manufacturing will develop a baseline plan describing the manufacturing methodology to be employed in producing the booster stage. The plan will outline basic manufacturing assembly breakdowns, tooling concepts, and stationization in addition to special tooling, handling equipment, special test equipment, and system safety requirements. The Manufacturing Plan will reflect the results of applicable tradeoff studies involving items such as tank fabrication problems, thermal protection system panel fabrication, and composite material cap applicable to titanium structures. These results are to be obtained from company-sponsored investigations. The plans and all pertinent supporting data will be submitted to NR for inclusion in Facility Utilization and Manufacturing Plan (TM001M).

Company:	Function:	Manager:
Chrysler Corporation (subcon)	Manufacturing	M. Elchison

3. Assist General Dynamics/Convair with the booster manufacturing portion of the Facilities Utilization and Manufacturing plan. This effort will concentrate on propellant tank assembly, mating of fuel tanks and other structures, plus final assembly tasks.

Company:	Function:	Manager:
GD/C	Operations Engineering	R. E. Soper

4. In support of the preparation of the Facility Utilization and Manufacturing Plan, provide the Test and Operations effort required to define preliminary facility requirements relating to test and provide initial estimates of the test facility need dates and vehicle test and support equipment installation and checkout schedules.

Company:	Function:	Manager:
GD/C	GSE and Facilities	M. E. Stone

5. Provide GSE and facilities design and analysis to satisfy development test requirements in support of the booster development test program.

WBS Number: 4.5.4
Booster Tasks (Cont)

a. Conduct modification design concepts of GSE and facilities in support of the ground test program.

b. Conduct design concepts of GSE and facilities to support the flight test program.

SPACE SHUTTLE PHASE B
TASK DESCRIPTIONS

WBS TITLE: TEST PLAN

WBS Number 4.5.5
Integration Tasks

Company:	Function:	Manager:
NR	Test and Operations	W. Edson

1. Prepare a preliminary space shuttle test plan which describes the overall test program including development, qualification, and acceptance (include buildup, in-process, and end item) testing with the primary objective of achieving operational flight status of the space shuttle at a substantially lower cost than expended on previous programs.

   a. Analyze orbiter and booster design for areas amenable to test commonality.

   b. Integrate the test philosophy, criteria, methods, requirements, programs, and plans where orbiter and booster reflect common hardware usage or where interfaces permit concurrent testing.

WBS Number: 4.5.5
Orbiter Tasks

Company:	Function:	Manager:
NR	Test and Operations	W. Edson

1. Evaluate and document the results of the company-sponsored hypersonic test approach and the manned versus unmanned test flight - orbiter trade studies to determine the best methods for safely achieving transonic, supersonic, and hypersonic flight.

2. Coordinate the delineation of input conditions and direct the optimization of the flight test vehicle trajectory.

3. Coordinate test-oriented design requirements with the vehicle designers for the operational vehicle, test articles, and test elements.

WBS Number: 4.5.5
Orbiter Tasks (Cont)

a. Review test vehicle design for compatibility with vehicle characteristics used in the test vehicle trajectory optimization; stability, performance, and loads predictions; and flight test program definition.

b. Coordinate testability requirements for the operational vehicle during vehicle design integration.

c. Review design changes for impact on vehicle testability in the development, qualification, and acceptance test programs.

4. Evaluate and document the results of the Company-sponsored studies consisting of:

a. Evaluation of the baseline checkout system for acceptance checkout of the operational vehicle as well as the optimum integration of the on-board checkout system upstream into the development/ qualification test program

b. Definition of the requirements for test facilities and support equipment as applicable to the ground and flight test program, including purpose, estimated usage time, and resources

c. Integration of all test information into a test program delineating the cost-effective method selected to accomplish development, qualification, and acceptance testing, using MHB 8080.1 and 8080.3 as a test guideline

d. Identification of the potentiality of items for causing substantial program impact

5. Prepare the Phase C/D preliminary test plan outline, draft, and final document based on the results of Company-sponsored studies, tradeoffs and study tasks defined in Task 2.1.1.

6. Evaluate and document the results of the Company-sponsored effort to define the test documentation required for the accomplishment of the Phase C/D task.

WBS Number: 4.5.5
Orbiter Tasks (Cont)

Company:	Function:	Manager:
NR	Manufacturing	J. W. Cuzzupoli

7. Provide to Test and Operations the manufacturing detail, subassembly, and top-level test requirements to support overall test program definition and formulation of the test plan. In addition, provide an identification and evaluation of the corresponding ground support equipment and facilities.

WBS Number: 4.5.5
Booster Tasks

Company:	Function:	Manager:
GD	Test and Operations	Malloy

1. Evaluate and document the results of the Company-sponsored study to determine the best methods for safely achieving transonic, supersonic, and hypersonic flight. Trade study will consider horizontal takeoff flight and both single and mated vertical launches as approaches.

2. Evaluate and document the results of Company-sponsored studies consisting of:

   a. Test documentation required for comprehensive reporting.

   b. Management approaches for visibility into program status, for control of costs and schedules, and for assurance that test objectives are achieved

   c. Safety analysis and failure mode effects and criticality (FMEC) analyses

   d. Abort analysis

   e. Maintainability and reliability analyses

   f. Aerodynamic performance and trajectory analyses

WBS Number: 4.5.5
Booster Tasks (Cont)

g. Flight-test instrumentation and measurement requirements to determine commonality with on-board checkout capability

h. Test requirements and determination of test programs for individual vehicle subsystems, GSE, and facilities

3. Analyze test program background data to verify booster test planning approaches to reduce cost without jeopardizing confidence or the ability to demonstrate capability.

   a. The best engineering methods and technical principles from past programs on launch vehicles, spacecraft and aircraft development programs will be merged to achieve a minimum-cost test plan.

   b. Individual test requirements and test plans defined as the result of test analyses for each subsystem will be integrated to create an optimized total test program. Multiuse of test articles and facilities will be considered for cost reduction.

4. Review and use the guidelines of NHB 8080.1 and 8080.3 to prepare a Phase C/D preliminary test plan outline, draft, and final report which will provide for:

   a. Definition of all tests to be performed and specific hardware configuration for each test

   b. Facilities and resources required for each test, the test location, and the calendar time period

   c. An overall planning chart, similar to the Certification Test Network (CTN), showing the logical integration of development, qualification, acceptance, and demonstration tests

SPACE SHUTTLE PHASE B
TASK DESCRIPTIONS

WBS TITLE: LOGISTICS AND MAINTENANCE PLAN

WBS Number: 4.5.6
Integration Tasks

Company:	Function:	Manager:
NR	Test and Operations	W. Edson

1. The data developed from previous tasks (2.1.3, Operations Analysis, and 2.1.9, Maintainability) will be used to prepare a plan describing the methodology, procedures, activities and schedules of the logistics support elements required for the successful operation of the Space Shuttle Program.

   a. The advanced airline maintenance techniques developed by AAL and the established NR/GD and AAL computerized support models evaluated in Phase B will be further expanded for detailed implementation in Phase C/D as applicable.

   b. The plan will describe the maintainability program to be imposed as a design discipline, relating the analysis of maintenance tasks to qualitative design criteria.

   c. The plan will also include a description of the training required for the booster and/or orbiter ground and flight crews and maintenance personnel.

   d. The plan will further quantify, to the extent permitted by design definition, requirements for technical documentation and the means for rapid retrieval and display of maintenance data.

   e. The plan will define transportation, packaging, and handling requirements for the transporting of vehicles, equipment end items, and spares from the manufacturing point through test phases and to the launch site.

   f. Propellant, pressurant, and cooling requirements at test, ferry, and alternate landing sites will also be identified.

WBS Number: 4.5.6
Integration Tasks (Cont)

g. The plan will describe the program to select, acquire, replenish, store, and issue spares and support equipment through the life cycle of the program.

h. The plan will define the maintenance plan, including levels of maintenance and sequential procedures for scheduled and unscheduled maintenance actions to satisfy the availability requirements of the orbiter vehicle.

2. The plan will provide for the controlling, updating, storing, and assigning support and test equipment to successive phases of development, test, and operations compatible with orbiter schedules. In addition to the data described above, the plan will define capabilities, duties, and responsibilities of field service personnel and recommend assignment specialties and phasing. The completed plan will establish the framework of logistics efforts to be implemented in Phases C/D of the program.

WBS Number: 4.5.6
Booster and Orbiter Tasks

Company:	Function:	Manager:
NR	Test and Operations	W. Edson
GD/AA		A. H. Gress/J. Amacker

1. Initial draft material will be prepared by NR and GD as listed below. Periodic review and comments on the plan drafts will be made by NR, GD, and AA; assignments for expansion and revisions will be directed.

WBS Number: 4.5.6
Booster and Orbiter Tasks (Cont)

	NR	GD	AA
Maintenance plan	*S	P	S
Maintainability	P	S	S
Support and test equipment	S	P	S
Field service support	P	S	S
Transportation handling and packaging	P	S	S
Propellants pressurants and coolants	S	P	S
Supply support	P	S	S
Training and personnel requirements	S	P	S
Support documentation	P	S	S
Training	S	P	S

*S = Support responsibility
P = Prime responsibility

SPACE SHUTTLE PHASE B
TASK DESCRIPTIONS

WBS TITLE: PROGRAM COST AND SCHEDULE ESTIMATES PLAN

WBS Number: 4.5.7
Integration Tasks

Company:	Function:	Manager:
NR	PP&C/Administration	Weinberg

1. Plan, coordinate, integrate, and prepare the cost and schedule estimates plan in accordance with DRL Item 19 as follows:

    a. At the end of the eighth month, submit a preliminary plan, with the exception of Form B, for review.

    b. At the end of the 12th month, submit the final complete plan in fulfillment of the contract requirements.

2. See WBS 4.8 for coverage of the cost analyses and trades leading to the baselines for the preliminary and final plans covered herein. The estimates in these plans will be based on CER's, factors, individual task estimates, and subcontractor inputs as deemed most appropriate and defined in supporting plans of action.

Company:	Function:	Manager:
NR	System Engineering	Bates

3. Prepare technical characteristics data per the preceding requirements.

WBS Number: 4.5.7
Orbiter Tasks

Company:	Function:	Manager:
NR	PP&C/Engineering	Weinberg/Bates

1. Prepare the orbiter elements of the cost and schedule estimates plan in support of 4.5.7, Integration Tasks. In addition to the primary efforts

WBS Number: 4.5.7
Orbiter Tasks (Cont)

of PP&C and Engineering, support from all functions will be provided in the areas of cost, schedule, and program definition and documentation.

WBS Number: 4.5.7
Booster Tasks

Company:	Function:	Manager:
GD	Economic Analysis	Kantor

1. Prepare the booster elements of the cost and schedule estimate plan in support of 4.5.7, Integration Tasks.

Company:	Function:	Manager:
GD	Business Operations	G. E. Putness

2. In conjunction with booster engineering, manufacturing, procurement and subcontractors, reliability, and QA, coordinate the planning and preparation of Phase C/D schedule data, as described above, in a format suitable for integration with cost data into the final documentation.

Company:	Function:	Manager:
GD	Division Estimating	J. Cannaday

3. As required, utilize detailed estimation techniques in point estimate studies to establish critical booster subsystem and vehicle costs. In conjunction with booster engineering, coordinate descriptive data with vendors to establish subsystem, facility, GSE, or other costs.

SPACE SHUTTLE PHASE B
TASK DESCRIPTIONS

WBS TITLE: PROGRAM ACQUISITION PLANS INTEGRATION

WBS Number: 4.5.8
Integration Tasks

Company:	Function:	Manager:
NR	Program and Systems Integration	W. F. Ezell

1. Establish definition, requirements, and guidelines for the preparation of the program acquisition plans.

2. Schedule and approve plan outlines.

3. Conduct periodic reviews, both in-house and with NASA, to control and assure continuity and compatibility of efforts during the development and preparation of each acquisition plan attendant to its content (including consistency of cost and schedule estimating relationships) and format.

4. Using Program Review Board processes, review for the Program Manager baseline program acquisition plans and any changes thereto; recommend approval.

Company:	Function:	Manager:
NR	System Engineering	J. Bates

5. Assist in coordination and review of all Phase C/D acquisition plans to assure consistency and technical integrity between engineering plans and all other plans, including baseline and final submittal to ERB, PRB, and NASA. Coordinate changes to plans.

Company:	Function:	Manager:
NR	Program and Systems Integration	F. J. Dore

6. Assist NR in accomplishing integration per above functions.

SPACE SHUTTLE PHASE B.
TASK DESCRIPTIONS

WBS TITLE: TECHNICAL DIRECTION INTEGRATION

WBS Number: 4.6
Integration Tasks

Company:	Function:	Manager:
NR	Program and Systems Integration	W. F. Ezell

1. Act as the focal point for receipt and timely disposition of all technical directives received from NASA, including required coordination with counterpart NASA personnel.

2. Determine functional areas affected and obtain from them necessary impact assignments. Maintain appropriate follow-up action.

3. Evaluate impact assessments received to determine total system effects (orbiter, booster, and integration effort) preparatory to (a) releasing a program directive implementing no-impact TD's or (b) notifying NASA in writing, within ten working days from data of TD receipt, of any impact to cost, schedule, or other contract provisions.

4. Using Program Review Board processes, review for the Program Manager impact-definition letters to NASA; recommend approval.

Company:	Function:	Manager:
GD	Program and Systems Integration	F. J. Dore

5. Assist NR in accomplishing integration per above function.

SPACE SHUTTLE PHASE B.
TASK DESCRIPTIONS

WBS TITLE: SYSTEM SAFETY PROGRAM

WBS Number: 4.7
Integration Tasks

Company:	Function:	Manager:
NR and GD	Program Management	J. P. Proctor, H. Nulton

An office of the Director of System Safety has been established for each program (booster and orbiter), and the directors serve as members of the staff to the respective program vice presidents. The directors of safety provide management direction and control for the integration of system safety into the respective programs and the overall Space Shuttle Program. Specific responsibilities of the directors of safety for their respective programs are as follows:

1. Act for the program vice president in the conduct of activities relating to all safety matters.

2. Provide a central coordination and control point for interface with the customer safety representatives.

3. Establish a system safety program to support all aspects of the Space Shuttle Program.

4. Establish a workable organization for the administration and conduct of the safety effort.

5. Establish policies and procedures for the conduct of the safety program.

WBS Number: 4.7
Orbiter and Booster Tasks

Company:	Function:	Manager:
NR and GD	Program Management	J. P. Proctor, H. Nulton

Specific system safety engineering tasks include:

1. Establish mutually acceptable procedures for the timely exchange of safety information and data between NR/SD, GD/Convair and subcontractors.

2. Establish mutually acceptable methodology for the conduct of system safety analyses.

3. Assure that safety applicable lessons learned on other programs are applied to the Space Shuttle Program.

4. Establish interface between all contractor activities to assure timely identification, evaluation, and assessment of safety problems.

5. Participate in design review activities to assure incorporation of safety requirements.

6. For NASA's coordination, prepare a briefing for NASA outlining the proposed system safety effort for Phase C/D.

SPACE SHUTTLE PHASE B
TASK DESCRIPTIONS

WBS TITLE: COST/DESIGN PERFORMANCE MANAGEMENT

WBS Number: 4.8
Integration Tasks

Company:	Function:	Manager:
NR	PP&C	Weinberg

1. Generate and maintain plans for the accomplishment of program cost/design performance management in support of shuttle cost objectives. These plans are to include:

    a. Definition of techniques and procedures which assure that cost is a major factor considered in design and tradeoff analyses and decisions. These shall be an integral part of the study contract and technical management process, including mandatory consideration of cost on all forms authorizing, reporting, or approving results of design studies and tradeoffs (e.g., study control sheets and design study control sheets).

    b. Definition of an NR/GD system of cost objectives budgeting and control. The definition shall be compatible with the liaison and reporting requirements described in the following paragraph. It shall also interface with the study control process.

    c. Coordination requirements with NASA to achieve cost estimate realism. NR/GD liaison and reporting requirements are to include (1) an analysis of current cost estimates related to cost objectives in a breakdown consistent with the NASA supplies Phase C/D Work Breakdown Structure, (2) assessments of the feasibility of meeting NASA cost objectives, and (3) recommendations for changes to NASA study control document requirements.

    d. Description of the NR/GDC cost/design performance management organization including organizational relationships, individual responsibilities of key personnel, and numbers and types of cost personnel. The role of costing personnel in the system/program definition process will be described.

WBS Number: 4.8
Integration Tasks (Cont)

2. Implement the proceding plan for the accomplishment of program cost/design performance management for the approved WBS elements of the Space Shuttle Program. The implementation will include the following activities:

   a. Develop and maintain trade and design study planning input data identifying cost and schedule considerations relative to selection of configuration alternatives, program elements affected, and evaluation data required, including: cost models, CER's, schedule spans, and mission models.

   b. Conduct cost analyses as part of the system/program definition process to estimate the cost impact to the total program baseline of all significant proposed system/program configuration changes.

   c. Establish appropriate cost budgets covering all subdivisions of work based upon the NASA program cost objective.

   d. Conduct an orientation program to identify responsible managers, their cost budgets, and the procedures used in establishing budgets and evaluating performance against budgets.

   e. Provide cost performance against the cost budget to each responsible manager to support periodic cost/budget performance reviews.

   f. Establish with NASA the baseline program cost estimate in the format of the jointly approved Phase C/D WBS. Conduct discussions to achieve an understanding of the realism of the baseline estimate.

3. Participate in discussions with NASA regarding Phase C/D WBS, schedule, cost, and technical baselines, as required.

WBS Number: 4.8
Orbiter Tasks

Company:	Function:	Manager:
NR	PP&C/SE	Weinberg/Bates

1. Support the development of plans described in 4.8, Integration Tasks, specifically in the area of orbiter procedures, cost objectives, and personnel application.

WBS Number: 4.8
Orbiter Tasks (Cont)

2. Implement all elements of the plan described in 4.8, Integration Tasks, for the orbiter design.

WBS Number: 4.8
Booster Tasks

Company:	Function:	Manager:
GD/C	Economic Analysis	Kantor

1. Support the development of plans described in 4.8, Integration Tasks, specifically in the area of booster procedures, cost objectives, and personnel application.

2. Implement all elements of the plan described in 4.8, Integration Tasks, for the booster design.

4.0 MANPOWER ALLOCATION

(Equivalent Man-Months)

WBS Element	Contributor	Months From Go-Ahead												
		1	2	3	4	5	6	7	8	9	10	11	12	Total
1.1	NR		Indirect											
1.2	NR		Indirect											
1.3	NR		Indirect											
1.4	NR		Indirect											
	GD	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.5	0.5	0.5	5.1
1.5	NR		Indirect											
	GD	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.5	0.5	0.5	5.1
1.6	NR		Indirect											
	GD	0.4	0.4	0.4	0.4	0.4	0.4	0.3	0.3	0.3	0.2	0.1	-	3.6
2.1.1	NR	4.2	5.2	8.7	9.2	9.2	7.7	8.0	7.4	6.7	6.8	6.4	5.0	84.5
2.1.2	NR	1.5	2.6	2.6	2.6	2.6	2.6	1.6	1.6	1.6	1.6	1.6	-	22.5
2.1.3	NR	2.2	4.7	6.0	5.9	6.1	5.3	3.5	2.3	2.1	1.0	1.1	0.3	40.5
	Subcon	1.0	1.3	1.6	1.8	2.1	2.1	2.0	1.4	1.1	1.1	0.9	0.6	17.0
2.1.4	NR	2.0	2.0	2.5	2.0	2.0	1.8	2.0	2.0	2.5	2.0	1.0	0.2	22.0
2.1.5	NR	3.1	3.0	4.1	4.5	3.1	5.0	5.6	5.0	3.1	2.0	1.0	-	39.5
2.1.6	NR	3.0	4.3	4.7	6.9	7.3	8.2	7.3	5.5	1.3	1.1	0.9	-	50.5
2.1.7	NR	1.9	4.2	4.8	3.5	4.0	3.0	1.5	1.5	-	-	-	-	24.4
2.1.8	NR	3.5	4.0	4.5	5.0	5.0	5.0	5.0	4.5	4.3	3.8	2.8	-	47.4
2.1.9	NR	0.6	0.6	0.6	0.8	0.9	0.9	0.9	0.9	0.6	0.3	0.2	-	7.3
	Subcon		Included in WBS Element 2.1.3											
2.1.10	NR	-	1.0	2.0	2.0	2.0	2.0	-	-	-	-	-	-	9.0
2.1.11	NR	0.1	1.0	2.1	2.0	2.1	2.1	0.1	-	-	-	-	-	9.5
	Subcon		Included in WBS Element 2.3.2											
2.1.12	NR	0.9	1.9	1.9	1.9	1.9	1.5	1.5	1.5	-	-	-	-	13.0
	Subcon		Included in WBS Element 2.3.2											
2.2.1	NR	6.7	7.0	7.0	6.9	9.9	4.5	2.5	2.5	-	-	-	-	47.0
2.2.2	NR	4.0	6.0	6.5	6.0	7.0	8.0	3.0	3.0	2.0	6.0	5.0	2.0	58.5
2.2.3	NR	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	12.0
2.2.4	NR	4.2	6.3	7.8	6.8	6.3	5.3	8.4	7.4	6.8	2.3	1.8	0.1	63.5
2.2.5	NR	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	1.0	23.0
2.3.1	NR	6.1	8.2	7.1	7.1	5.2	4.2	2.6	2.6	2.6	2.6	2.5	1.5	52.3
2.3.2	NR	5.7	6.2	7.0	5.1	6.7	7.8	7.6	6.1	5.0	2.0	2.0	-	61.2
	Subcon	19.0	25.5	28.3	31.6	32.1	31.4	29.7	34.2	12.1	8.3	7.7	-	259.9
2.3.3	NR	0.2	0.3	0.5	0.5	-	0.5	-	-	-	-	-	-	2.0
2.3.4	NR	0.3	0.9	1.1	0.6	0.4	0.2	0.5	0.5	-	-	-	-	4.5
2.3.5	NR	1.0	2.0	2.0	1.2	0.7	0.7	0.7	0.7	0.5	0.5	0.5	0.5	11.0
2.3.6	NR	1.0	2.1	4.5	1.6	2.0	2.1	1.5	0.6	0.5	0.6	0.5	0.5	17.5
2.3.7	NR	1.8	3.0	3.3	3.3	3.3	3.3	2.3	2.2	2.0	0.5	0.5	0.5	26.0
2.3.8	NR	0.3	0.3	0.3	0.2	0.1	0.1	-	-	-	-	-	-	1.3
2.3.9	NR	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	-	-	10.0
	Subcon	3.8	5.6	6.1	7.0	6.7	6.0	4.7	2.6	1.8	1.5	-	-	45.8

Manpower Allocation (Cont)

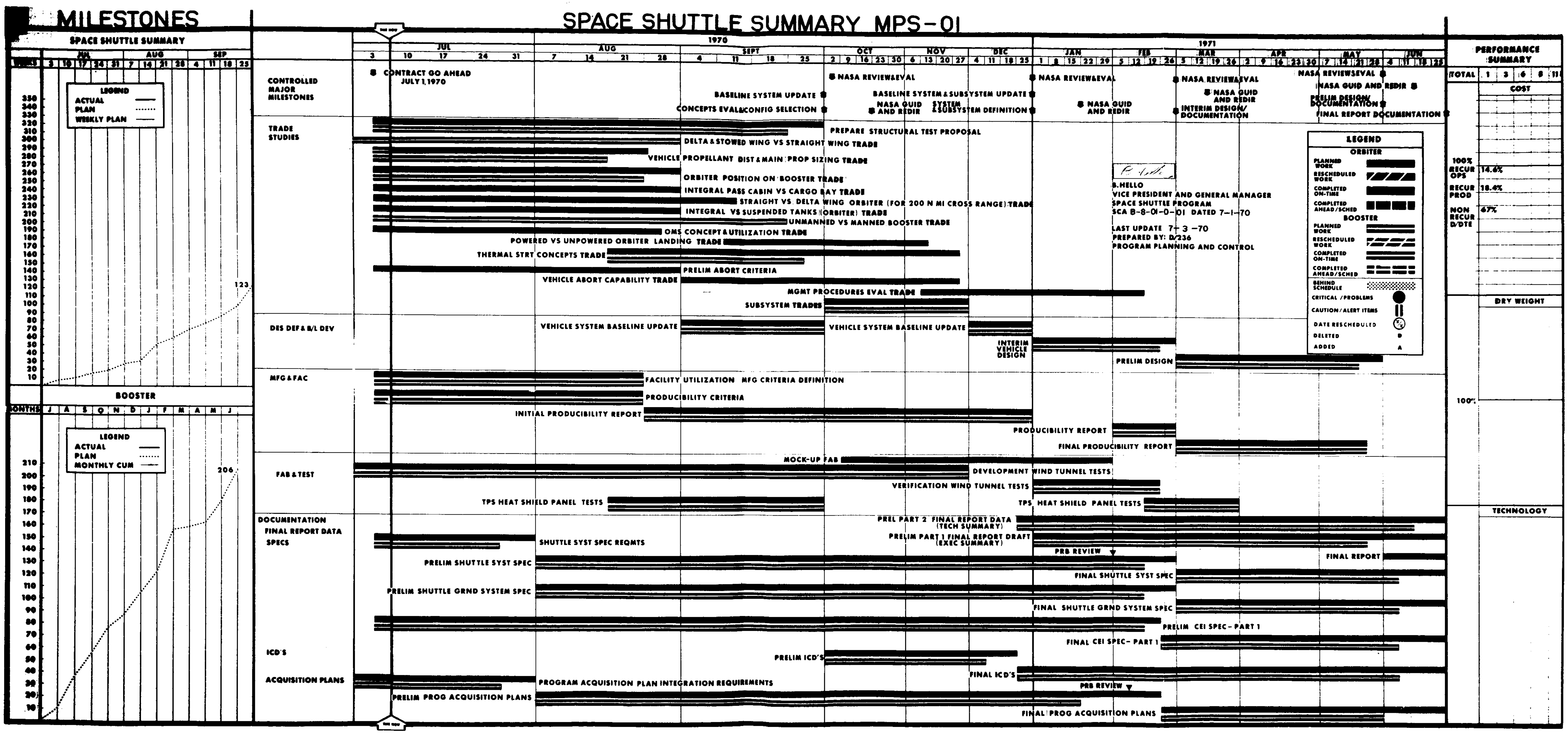
(Equivalent Man-Months)

WBS Element	Contributor	Months From Go-Ahead												
		1	2	3	4	5	6	7	8	9	10	11	12	Total
2.3.10	NR	0.3	0.3	0.3	0.2	0.1	0.1	-	-	-	-	-	-	1.3
2.4.1	NR	2.5	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.2	1.7	30.7
2.4.2	NR	-	-	-	-	-	9.0	12.5	13.5	13.5	7.5	5.5	1.5	63.0
2.4.3	NR	-	-	2.0	20.0	34.5	17.0	9.5	3.0	1.0	0.5	0.5	0.5	88.5
2.4.4	NR	-	-	-	0.5	0.7	1.2	1.2	0.7	0.7	0.7	0.9	0.4	7.0
2.4.5	NR	-	-	-	-	-	-	0.5	0.5	0.5	0.5	-	-	2.0
2.5	NR		Indirect											
2.6.1	NR		Included in WBS Element 4.1											
2.6.2	NR		Included in WBS Element 4.2											
2.6.3	NR		Included in WBS Element 4.3											
2.6.4	NR		Included in WBS Element 4.4											
3.1.1	GD	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.6	20.3
3.1.2	GD	0.7	0.7	1.0	1.0	1.2	1.6	1.7	1.6	0.8	0.2	0.2	0.2	10.9
3.1.3	GD	0.3	0.4	0.4	0.5	0.5	0.5	0.7	0.5	0.5	0.3	0.2	0.2	5.0
	Subcon	2.7	4.0	4.1	4.3	4.4	4.4	5.3	5.0	3.7	3.7	2.5	0.3	44.4
3.1.4	GD	0.2	0.2	0.2	0.2	0.2	0.3	0.2	0.2	0.2	0.2	0.2	0.2	2.5
3.1.5	GD	3.4	4.1	3.2	3.0	2.4	4.1	4.2	4.3	2.6	1.0	0.6	-	32.9
3.1.6	GD	0.1	0.2	0.3	0.3	0.3	0.4	0.4	0.4	0.3	0.1	0.1	0.1	3.0
3.1.7	GD	0.3	0.6	0.7	0.7	0.8	1.0	0.7	0.4	0.3	0.1	-	-	5.6
3.1.8	GD	0.2	0.2	0.3	0.5	0.5	0.5	0.5	0.4	0.2	0.1	0.1	0.1	3.6
3.1.9	GD	0.1	0.2	0.3	0.2	0.3	0.3	0.2	0.1	0.1	0.1	0.1	0.1	2.1
	Subcon		Included in WBS Element 3.1.3											
3.1.10	GD	0.6	1.3	0.6	0.6	0.7	0.5	0.3	0.5	0.4	0.2	0.2	-	5.9
3.1.11	GD	0.1	0.1	0.1	0.8	0.2	0.2	0.2	0.2	-	-	-	-	1.9
3.1.12	GD	0.1	1.2	0.8	0.7	0.5	0.3	0.1	0.1	-	-	-	-	3.8
3.2.1	GD	0.5	0.5	1.2	0.8	0.6	0.4	0.6	0.5	0.2	0.2	0.3	0.1	5.9
3.2.2	GD	1.0	1.1	1.6	1.6	1.7	2.4	2.6	2.2	2.2	1.4	1.1	-	18.9
3.2.3	GD	0.5	0.5	0.6	0.6	0.8	1.1	0.9	0.7	0.5	0.4	0.2	0.1	6.9
3.2.4	GD	0.3	0.8	0.7	0.6	0.4	0.6	0.9	0.4	0.3	0.3	0.3	-	5.6
3.2.5	GD	0.5	0.5	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	7.0
3.3.1	GD	2.5	1.9	2.1	1.5	2.2	1.6	2.3	1.5	1.6	1.5	1.1	0.5	20.3
3.3.2	GD	1.3	1.7	1.7	2.3	2.8	2.3	2.4	2.2	2.2	1.7	1.8	1.9	24.3
	Subcon	3.2	4.5	5.1	5.4	5.3	4.9	4.3	4.5	1.7	1.3	1.2	1.0	42.4
3.3.3	GD	0.2	0.2	0.3	0.3	0.3	0.4	0.3	0.3	0.2	0.2	0.2	0.2	3.1
3.3.4	GD	-	-	0.1	0.3	0.3	0.3	0.2	0.1	0.1	0.3	0.2	0.2	2.1
3.3.5	GD	0.5	0.9	1.0	0.5	0.2	0.8	0.5	0.3	0.8	0.8	0.7	0.5	7.5
3.3.6	GD	0.2	0.2	0.2	0.4	0.5	0.5	0.3	0.3	0.3	0.4	0.4	0.2	3.9
3.3.7	GD	-	-	0.1	0.4	0.4	0.3	0.1	0.1	0.1	0.1	0.1	-	1.7
3.3.8	GD	0.2	0.2	0.2	0.2	0.2	0.3	0.2	0.2	0.2	0.2	0.3	0.2	2.6
	Subcon	1.0	1.4	1.5	1.6	1.5	1.3	1.0	0.7	0.6	0.5	0.4	-	11.5
3.3.9	GD	-	-	-	0.3	0.6	0.5	0.2	0.2	0.1	0.1	0.1	-	2.1

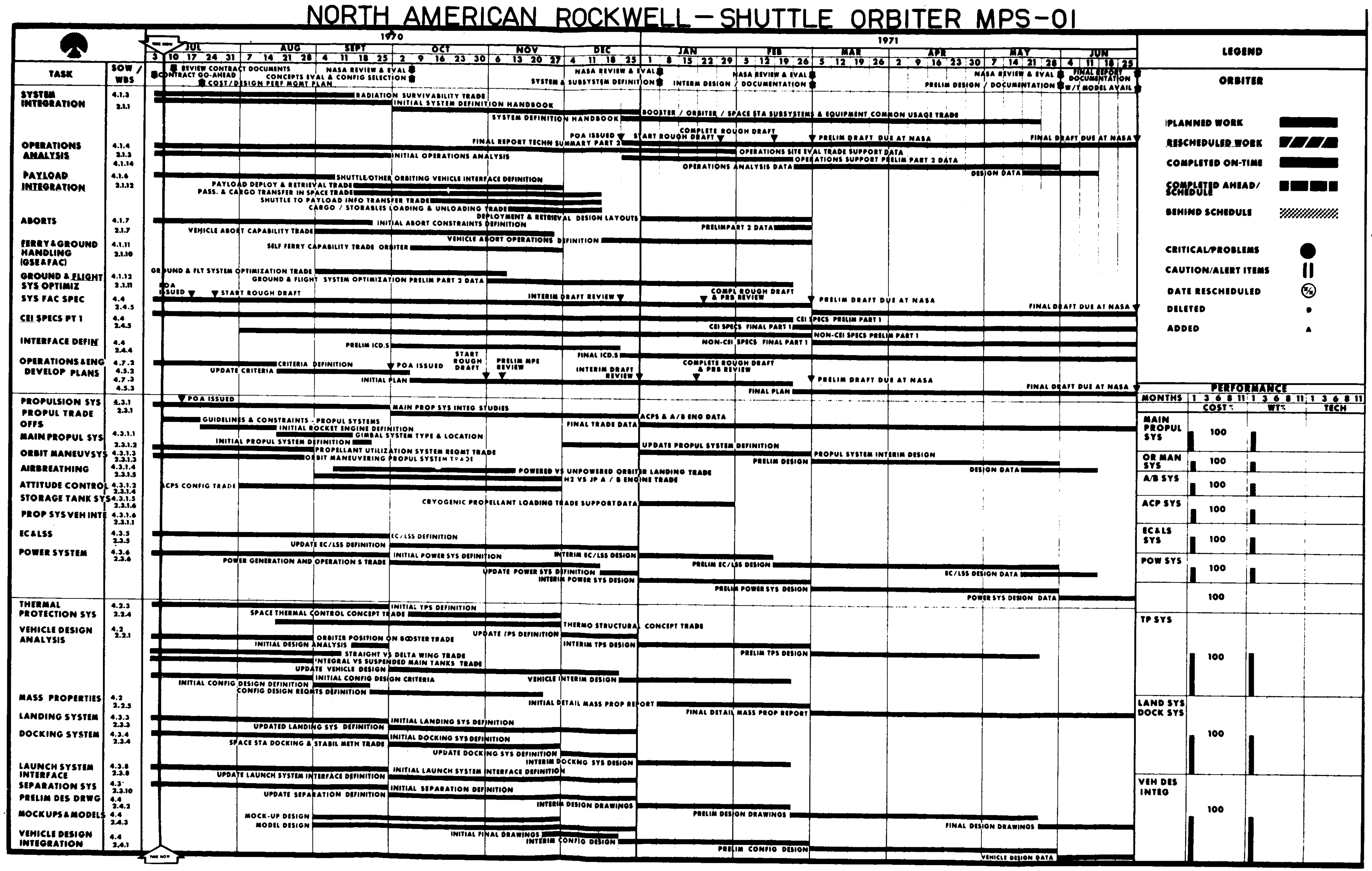
Manpower Allocation (Cont)

(Equivalent Man-Months)

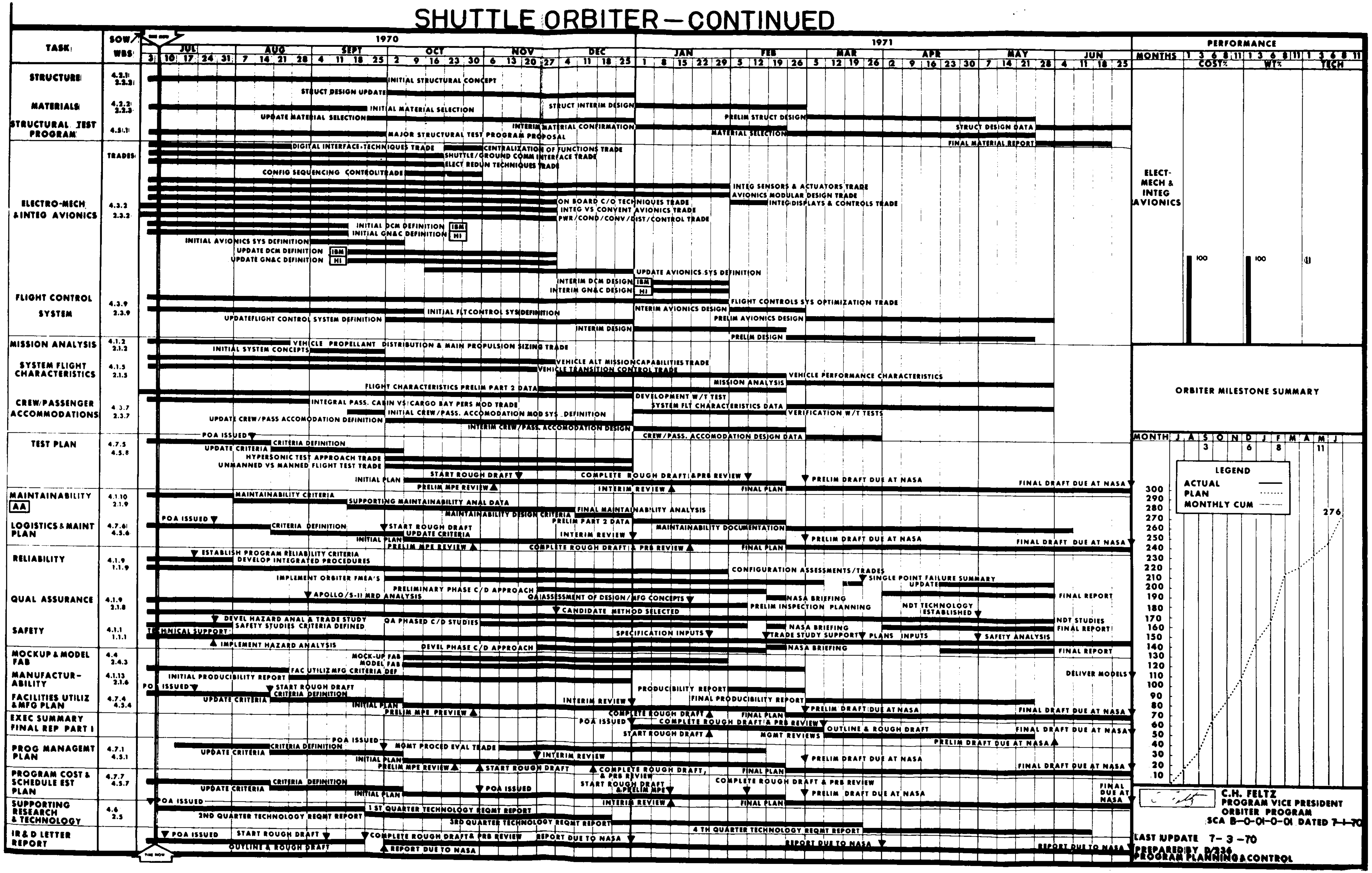
WBS Element	Contributor	Months From Go-Ahead												
		1	2	3	4	5	6	7	8	9	10	11	12	Total
3.4.1	GD	0.8	0.8	0.9	0.8	1.0	1.0	1.0	1.2	1.3	1.4	1.0	0.8	12.0
3.4.2	GD	1.9	2.5	3.1	5.6	5.7	10.7	16.9	14.3	11.3	8.8	4.2	1.0	86.0
3.4.3	GD	-	0.4	6.0	16.0	16.4	16.4	16.7	16.7	16.1	3.6	1.0	1.0	110.3
3.4.4	GD	0.6	0.6	0.7	0.7	1.3	1.6	2.4	2.2	2.4	2.2	1.7	0.6	17.0
3.4.5	GD	1.0	1.0	1.8	1.7	4.3	5.4	5.0	6.7	6.6	4.4	4.1	1.8	43.8
3.5	GD	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.2	0.3	0.2	0.3	0.3	3.4
3.6.1	GD	0.6	0.6	0.6	0.6	0.5	0.5	0.6	0.5	0.5	0.6	0.5	0.5	6.6
3.6.2	GD	0.5	0.5	0.5	0.6	0.6	1.0	0.7	0.8	0.8	0.7	0.6	0.2	7.5
3.6.3	GD	0.1	0.1	0.1	0.1	0.1	0.2	0.3	0.3	0.3	0.2	0.2	0.2	2.2
3.6.4	GD	-	-	-	-	-	-	-	-	-	-	-	6.8	6.8
4.1	NR	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.0	41.5
4.2	NR	1.5	1.5	4.0	2.5	2.5	2.5	2.5	8.0	4.0	4.0	17.0	19.9	69.9
4.3	NR	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.5	0.5	0.5	0.5	10.0
4.4	NR		Indirect											
4.5.1	NR	1.0	1.0	1.0	1.0	1.0	1.0	1.2	1.2	1.5	1.5	1.7	1.0	14.1
	GD	-	-	0.5	0.5	1.0	1.0	1.0	1.0	0.8	0.5	0.5	0.5	7.3
4.5.2	NR	-	-	-	-	-	0.5	0.5	0.4	0.2	0.2	0.2	-	2.0
	GD	-	0.2	-	-	-	-	0.6	0.5	0.3	0.2	0.1	0.1	2.0
4.5.3	NR	-	-		-	-	-	0.5	0.5	0.5	0.5	-	-	2.0
	GD	-	-	0.1	-	-	0.2	0.3	0.4	0.5	0.9	0.8	0.8	4.0
4.5.4	NR	3.7	5.8	7.2	11.7	12.3	7.7	7.5	6.1	5.4	5.2	3.3	1.9	77.8
	GD	-	-	0.2	0.8	0.8	0.8	0.7	0.7	0.7	0.7	0.6	-	6.0
	Subcon	2.0	2.0	1.5	1.5	1.0	1.0	3.0	4.0	3.0	2.0	1.0	-	22.0
4.5.5	NR	-	0.6	0.1	0.7	0.7	0.7	0.2	-	0.5	0.5	1.5	0.5	6.0
	GD	0.6	0.6	0.9	1.0	0.8	1.6	0.8	0.8	0.7	0.7	0.8	0.8	10.1
	Subcon		Included in WBS Elements 2.3.2 and 3.3.2											
4.5.6	NR	-	-	-	0.3	0.3	0.7	0.5	0.3	0.2	0.2	0.2	0.2	2.9
	GD	-	-	0.3	0.4	0.3	0.3	0.3	0.3	0.4	0.4	0.3	0.3	3.3
4.5.7	NR	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	-	11.0
	GD	-	-	-	-	0.4	0.4	0.5	0.5	0.4	0.4	0.4	0.4	3.4
4.5.8	NR		Indirect											
	GD	0.4	0.4	0.4	0.4	0.4	0.5	0.5	0.5	0.5	0.6	0.7	1.0	6.3
4.6	NR		Indirect											
	GD	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.2	0.2		4.0
4.7	NR		Indirect											
	GD	0.1	0.2	0.2	0.1	0.1	0.1	0.3	0.3	0.3	0.3	0.2	0.1	2.3
Subtotal	NR	72.8	98.2	118.4	134.7	152.1	134.4	114.9	104.2	81.3	66.1	68.8	43.7	1189.6
Subtotal	GD	24.0	29.2	38.2	51.8	56.5	67.1	73.4	69.4	62.2	40.4	30.1	25.2	567.5
Subtotal	NR/GD Subcon	32.7	44.3	48.2	53.2	53.1	51.1	50.0	52.4	24.0	18.4	13.7	1.9	443.0
Total		129.5	171.7	204.8	239.7	261.7	252.6	238.3	226.0	167.5	124.9	112.6	70.8	2200.1



Summary Master Program Schedule

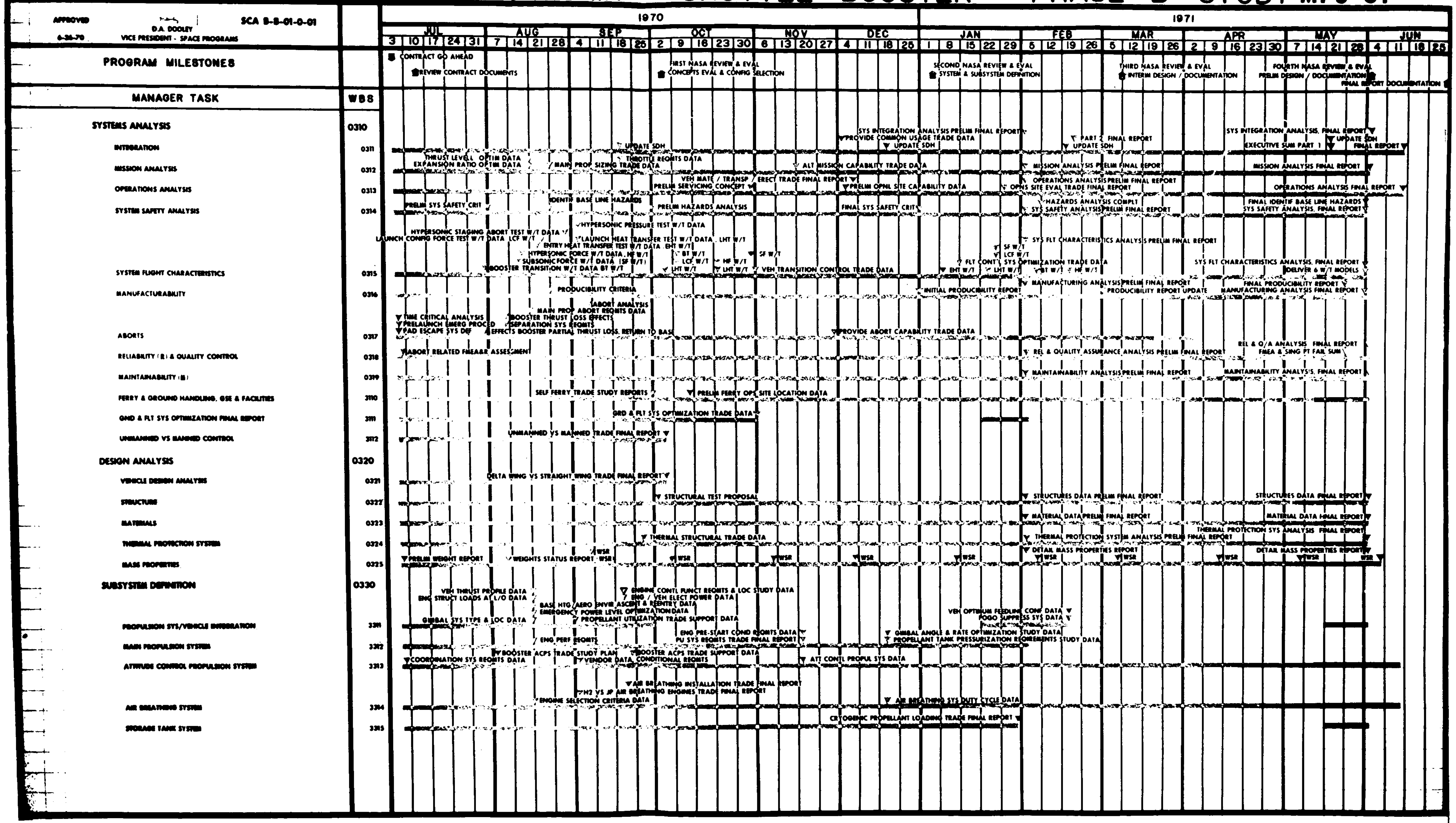


Orbiter Master Program Schedule (Sheet 1 of 2)



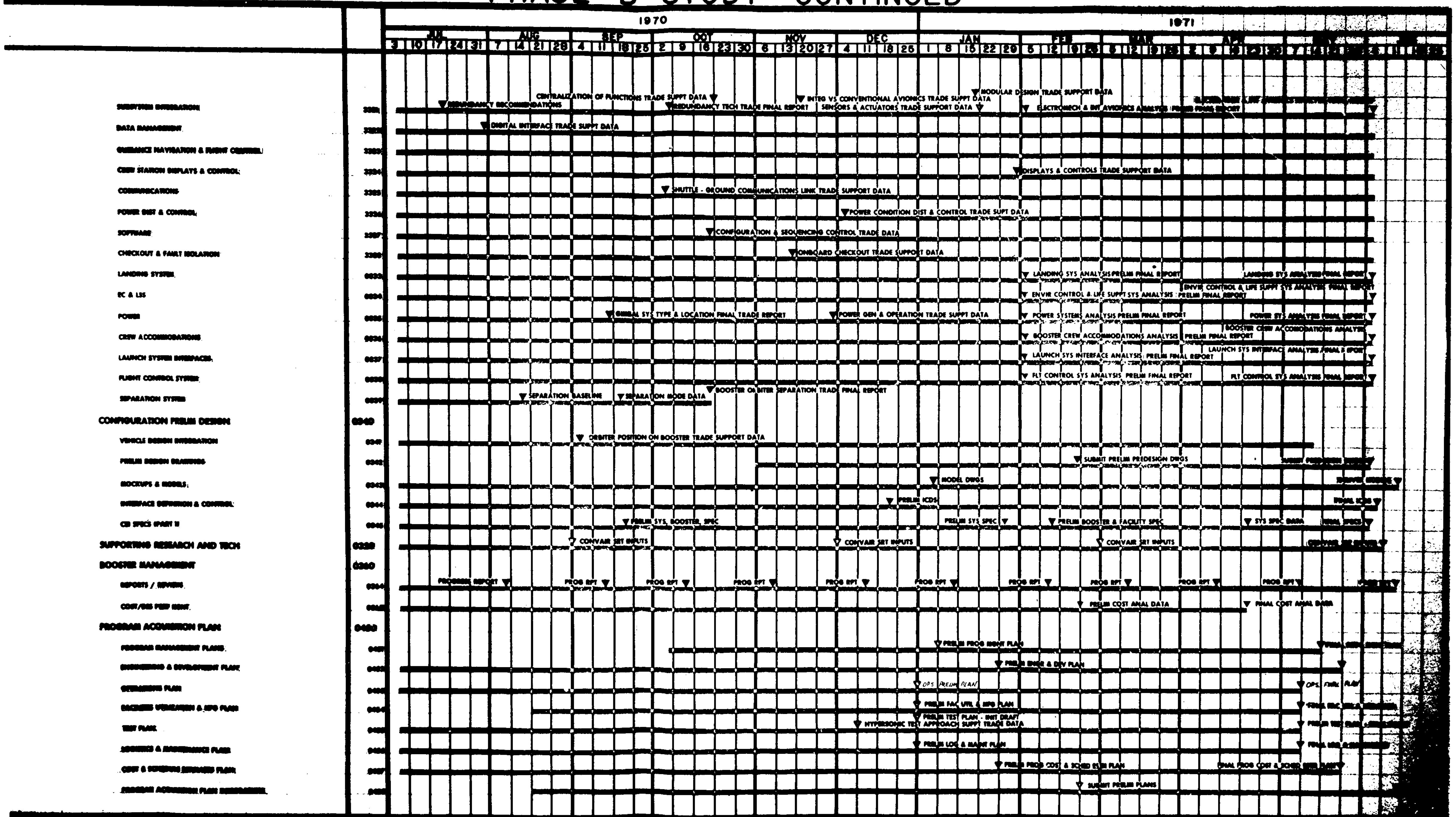
Orbiter Master Program Schedule (Sheet 2 of 2)

GENERAL DYNAMICS / CONVAIR - SHUTTLE BOOSTER - PHASE B STUDY MPS-01

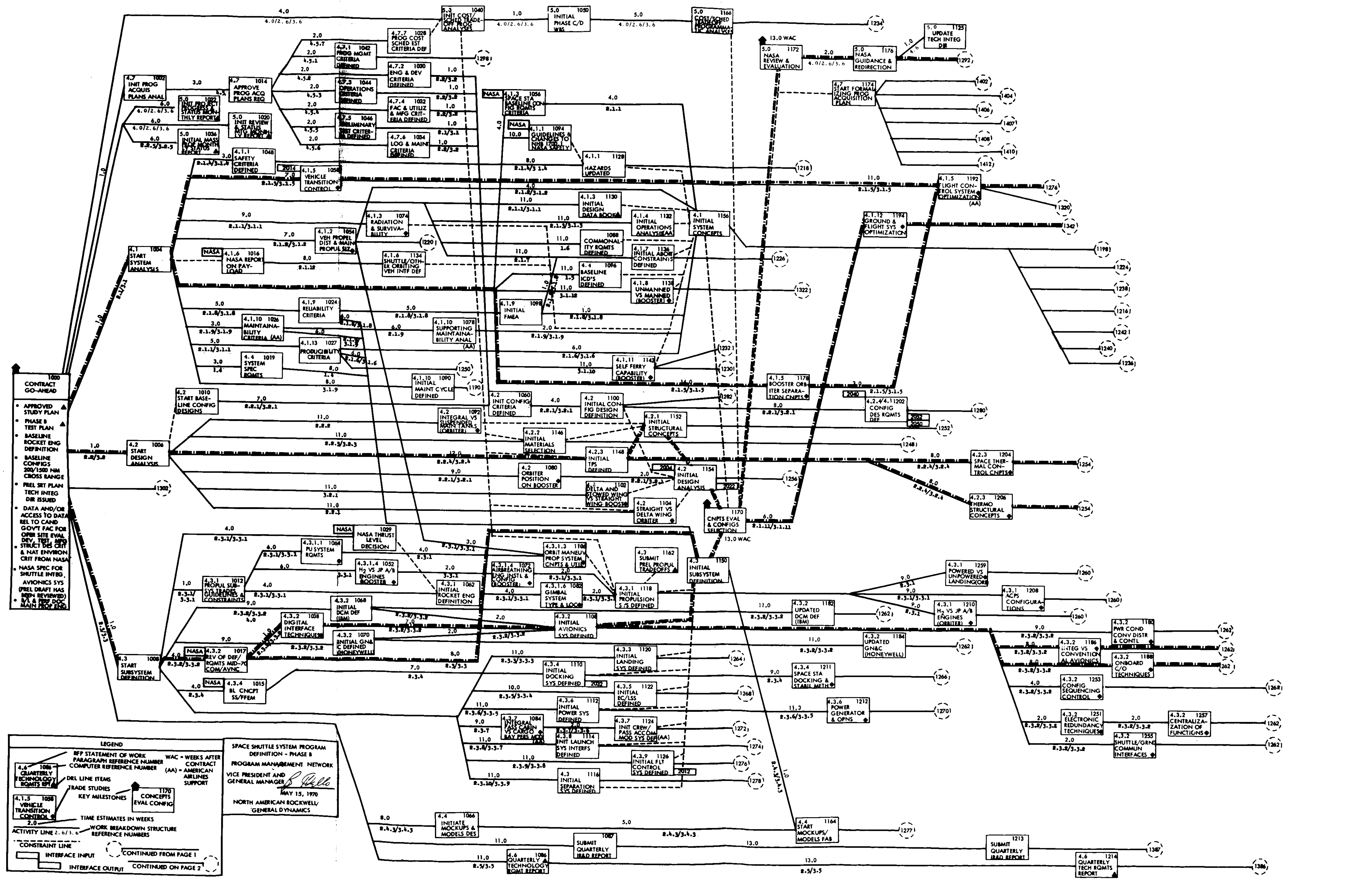


Booster Master Program Schedule (Sheet 1 of 2)

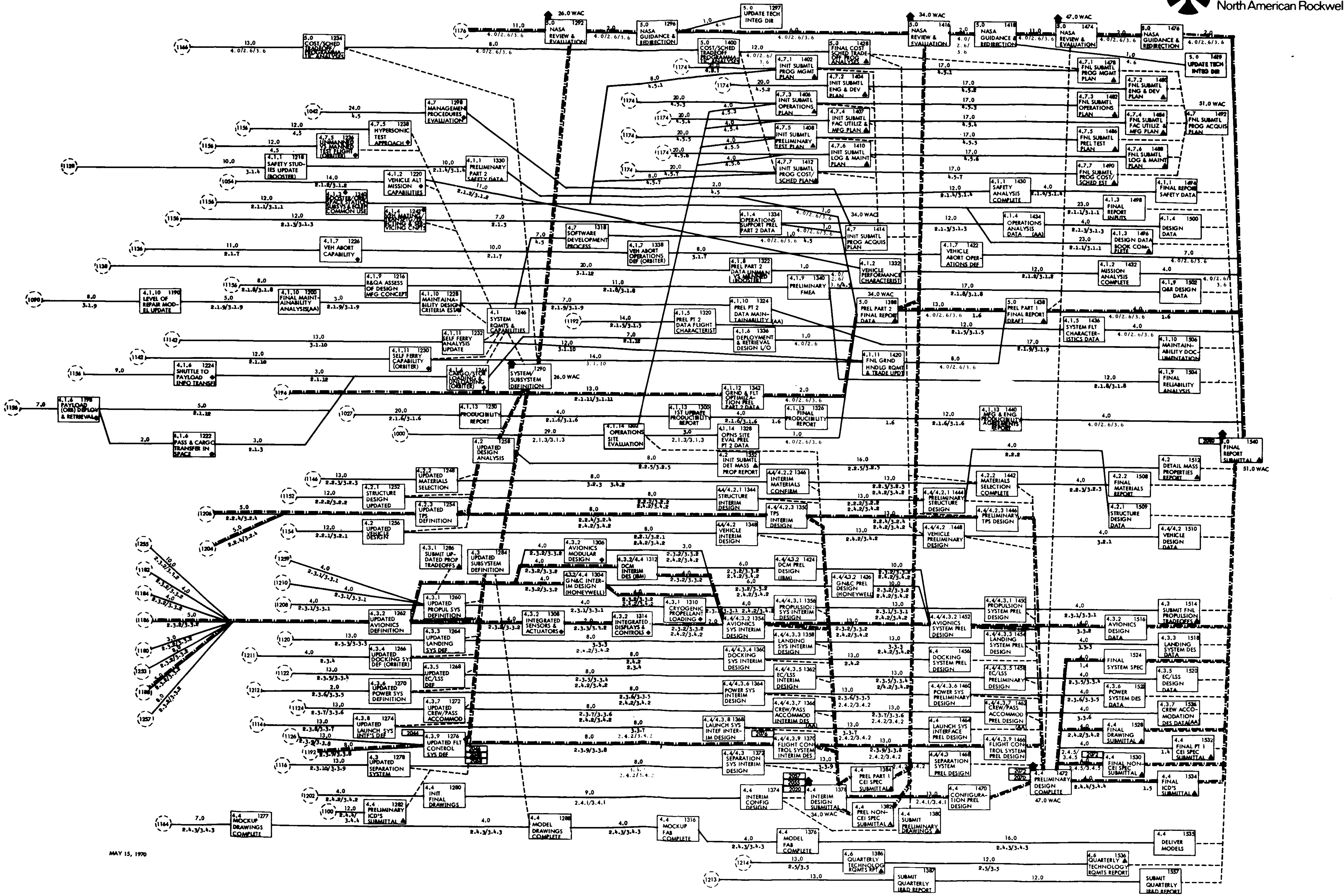
PHASE B STUDY—CONTINUED



Booster Master Program Schedule (Sheet 2 of 2)



Space Shuttle Phase B Program Management Network (Sheet 1 of 2)



Space Shuttle Phase B Program Management Network (Sheet 2 of 2)

6.0 SUPPORTING DOCUMENTATION

NASA will provide (or indicate a source from which to obtain), by agreed dates, supporting data contemplated in the Statement of Work to result from concurrent efforts of NASA, DOD, and other contractual sources when such data are specifically identified by the contractor and mutually determined appropriate to the Phase B. Study.

7.0 MANAGEMENT TECHNIQUES AND CONTROLS

The purpose of this section is to describe the management techniques, controls, and processes used to manage the Space Shuttle Program. The Study Plan is a guide and reflects the contractors approach toward accomplishing the contract requirements. All program resource planning is consistent with the Study Plan. Figure 7-1 shows the management activities that represent the resource control process. A description of these activities is contained in this section.

7.1 WORK AUTHORIZATIONS

All work authorizations (work packages) are keyed to the work breakdown structure (WBS) in the Study Plan. For reference to the WBS, see Section 2.0. The work authorization system is designed to "tree" the contract effort from the Space Shuttle Program vice president and general Manager (VP&GM) to the lowest subdivision work package by the use of program directives.

7.1.1 Program Directives

All effort on the Space Shuttle Program is authorized by a program directive issued by the Space Shuttle Program VP&GM and by the booster or orbiter program vice president (PVP). The program directive form is shown in Figure 7-2. Figure 7-3 depicts the type of data released by a program directive and to whom it can be directed.

7.1.2 Work Packages

Work packages are developed and issued at each management level. Each work package contains task requirements/statement of work, resources, and milestone schedules. The work package issued by the VP&GM will be at a summary level in comparison to the work package issued for a specific statement of work within an element of the WBS. The Space Shuttle Program will have work packages for the elements of the WBS. A responsible manager is accountable for the WBS resources, schedule, and technical performance. The work package flow is shown in Figure 7-4. A specimen WBS work package is shown in Figure 7-5.

The WBS forms the baseline for a cost accumulation structure. Each work package has a unique accounting number. Indenture codings mechanically accumulate the individual packages to the element of the WBS/responsible

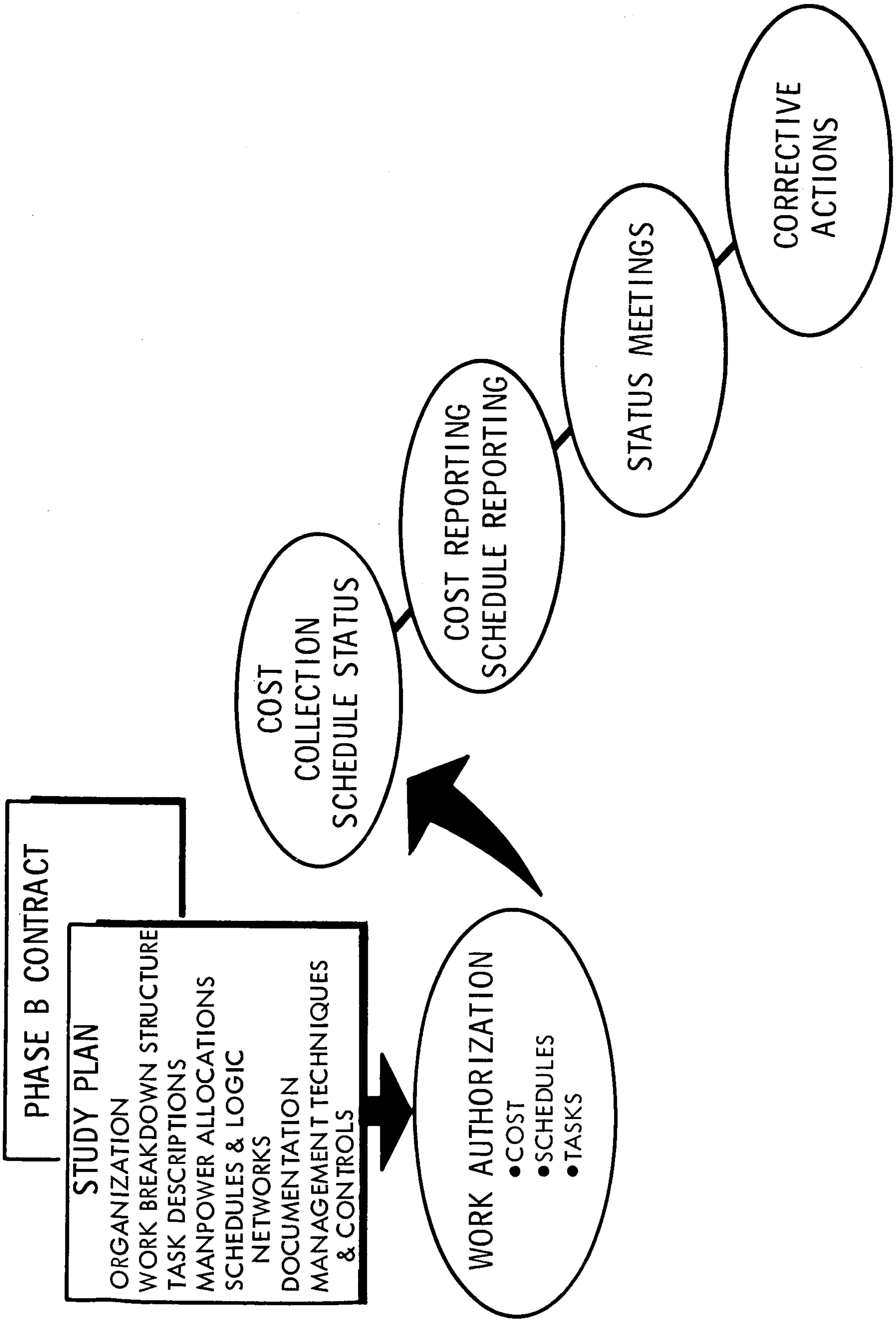


Figure 7-1. Program Control Process

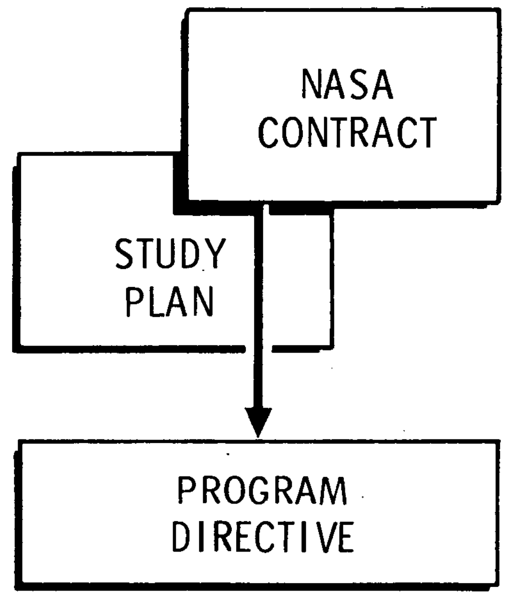
PAGE ____ OF ____

NUMBER	
DATE	

SPACE SHUTTLE PROGRAM DIRECTIVE

THIS PROGRAM DIRECTIVE AUTHORIZES EFFORT RELATED TO THE SUBJECT DENOTED ON THE FACE OF THIS DOCUMENT AND AS SUPPLEMENTED BY THE ATTACHMENT(S).
TO
EFFECTIVITY: ☐ ORBITER ☐ BOOSTER ☐ SPACE SHUTTLE SYSTEM INTEGRATION
SUBJECT:
REFERENCE:
AUTHORIZATION SIGNATURE: NAME ____ DEPT ____ DATE ____

Figure 7-2. Space Shuttle Program Directive Format



GOES TO

- ORBITER PROGRAM VICE PRESIDENT
- BOOSTER PROGRAM VICE PRESIDENT
- SYSTEM INTEGRATION PROJECT DIRECTOR

COVERS

- GENERAL ORDER
- MASTER PROGRAM SCHEDULE
- WORK PACKAGES
- COST ACCUMULATION STRUCT
- IMPLEMENTING INSTRUCTIONS
- REPORTING REQUIREMENTS
- SYSTEM INTEGRATION INSTRUCTIONS
- SUBCONTRACTOR PURCHASE ORDERS
- ETC.

Figure 7-3. Program Directive

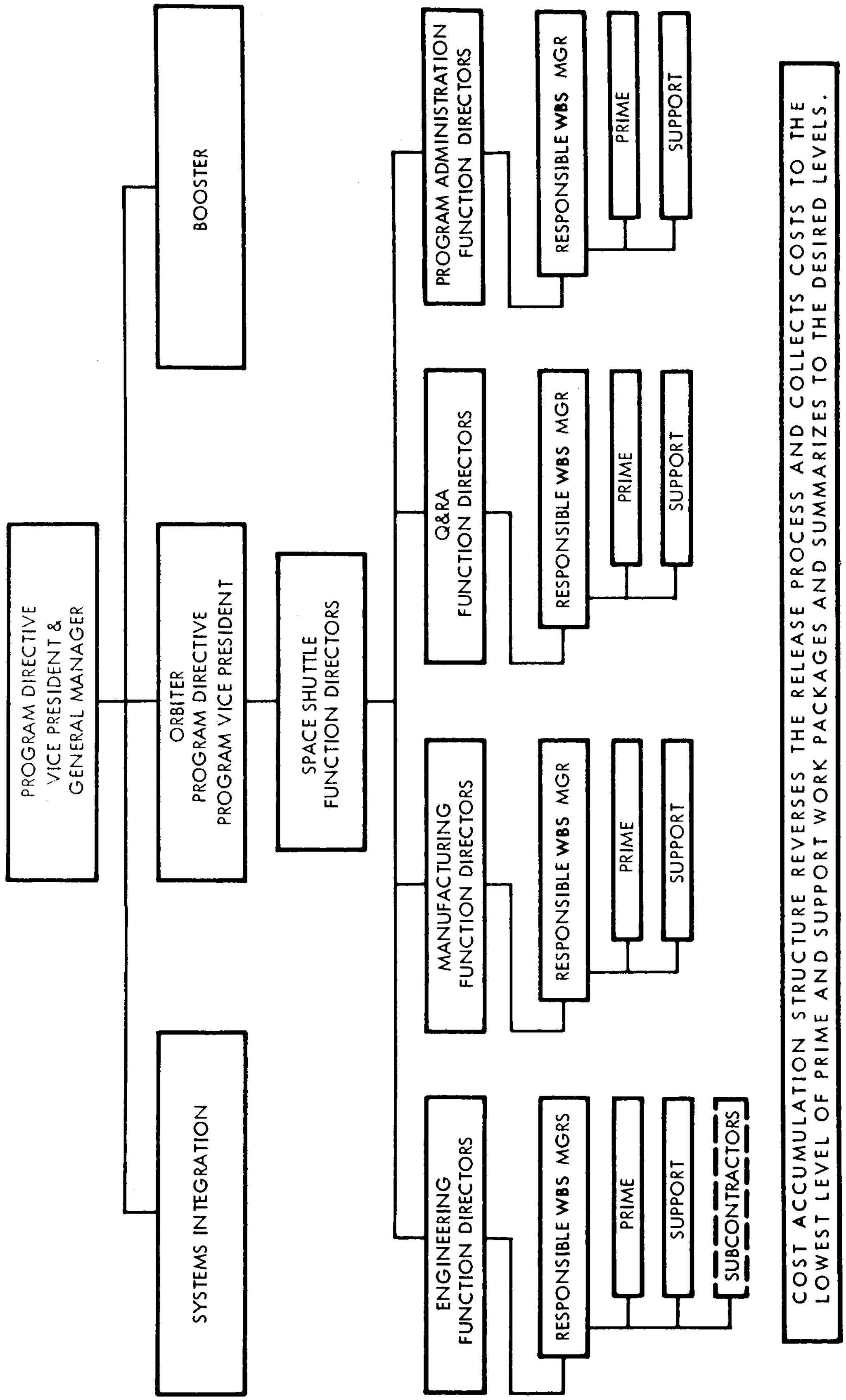


Figure 7-4. Work Package Flow

FUNCTION: System Engineering
MANAGER: J. Bates
WBS NO.: 2.1.1
WBS TITLE: Integration

DATE: April 8, 1970
W/P NO.: 11003 P
W/P TITLE: System Analysis

RADIATION SURVIVABILITY TRADE STUDY
COMPLETE PREL MEAS LIST
COMPLETE 1ST DRAFT DESIGN DATA BOOK
SCHEMATIC BLOCK DIAGRAM COMPLETE
POWER VS UNPOWERED ORBITER LANDING TRADE STUDY
COMMON EQUIP. USAGE TRADE STUDY
UPDATE & SUBMIT MEAS LIST TO NASA
UPDATE & SUBMIT DESIGN DATA BOOK

	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	TOTAL
M/M			2.0	3.0	4.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	4.0				53.0

TASK DESCRIPTION

1. Evaluate & document radiation survivability trade study related data.
2. Evaluate & document related data for the Shuttle Vehicle/Space Station common equipment usage trade study.
3. Support & evaluate the Powered vs Unpowered Orbiter Landing Trade Study.
4. Evaluate engineering system trade study results & maintain a Trade Studies Data Book consisting of a log of trade studies, study worksheets, & an overall trade study schedule. Document ERB actions & verify implementation of ERB decisions. Maintain a summary description & a history of the baseline configurations, & respective cost summaries, during Phase B & disseminate such data as required.
5. Prepare top level schematic block diagrams (SBD's) interrelating the space vehicle, other major system elements & the Space Station. Prepare a first level SBD interrelating the Orbiter & Booster.
6. Establish & maintain current the Design Data Book in accordance with DRB SE004M. This will be part of the baseline conceptual data in the Systems Definition Handbook.

Figure 7-5. Space Shuttle Program Phase B Contract manager. Further codings summarize the resource data at the levels desired. Resources are reported showing actual versus budget and the variance at each level. A sample section of the cost accumulation structure is shown in Figure 7-6.

7.2 INTERNAL REPORTING AND STATUSING

7.2.1 Cost Reporting

Cost reports are summarized to provide only the information that is required to properly identify problems and manage at each level of responsibility. Report levels are shown in Figure 7-7.

7.2.2 Schedule Reports

Control of the Space Shuttle Program is effected through a building block concept of schedules and milestones as portrayed in Figure 7-8. The illustration displays the flow of schedule control, schedule changes, and schedule status as described in the following paragraphs:

(A) The Space Shuttle Program Summary Master Schedule encompasses the overall program requirements and objectives as defined by controlled contract milestones, program definition milestones, and integration/interface milestones.

(B) The booster and orbiter program master schedules are composed of selected program milestones and key internal milestones. All milestones in the MPS (Section 5.0) appear on the booster or orbiter program master schedule.

(C) Functional manager schedules are an integral part of the building block concept in the control of program milestones. These schedules include the selected booster or orbiter milestones and supporting milestones from trades, analysis and documentation.

(D) The work package (WP) schedules are the base from which status is initiated and problems identified and resolved. Designated individuals have responsibility for each WP schedule. These schedules are composed of key functional and detail milestones related to the tasks, input and output interface events, and major program events that are to be achieved in order to accomplish the objectives of the work breakdown structure (WBS) elements.

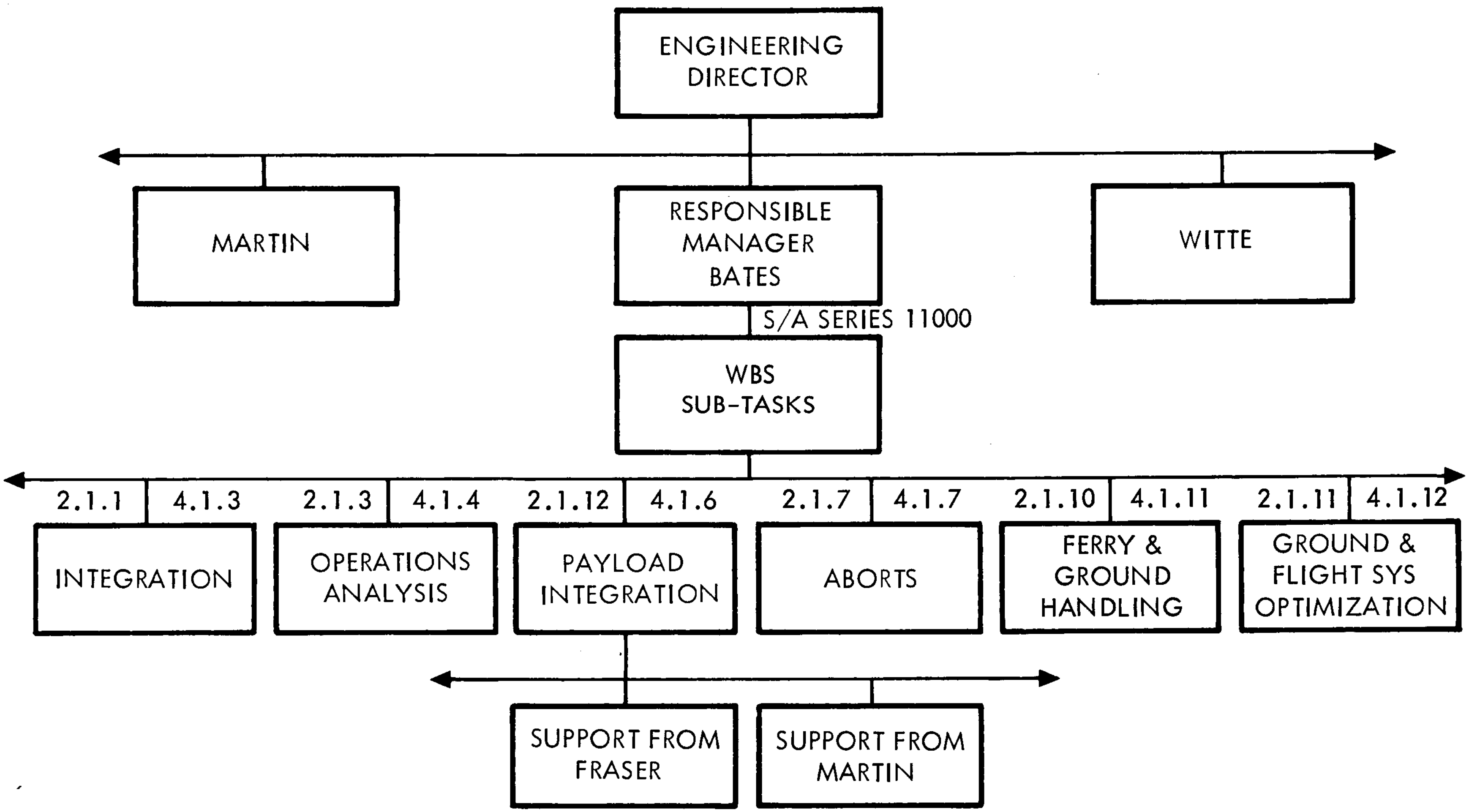


Figure 7-6. Sample Cost Accumulation and Feedback

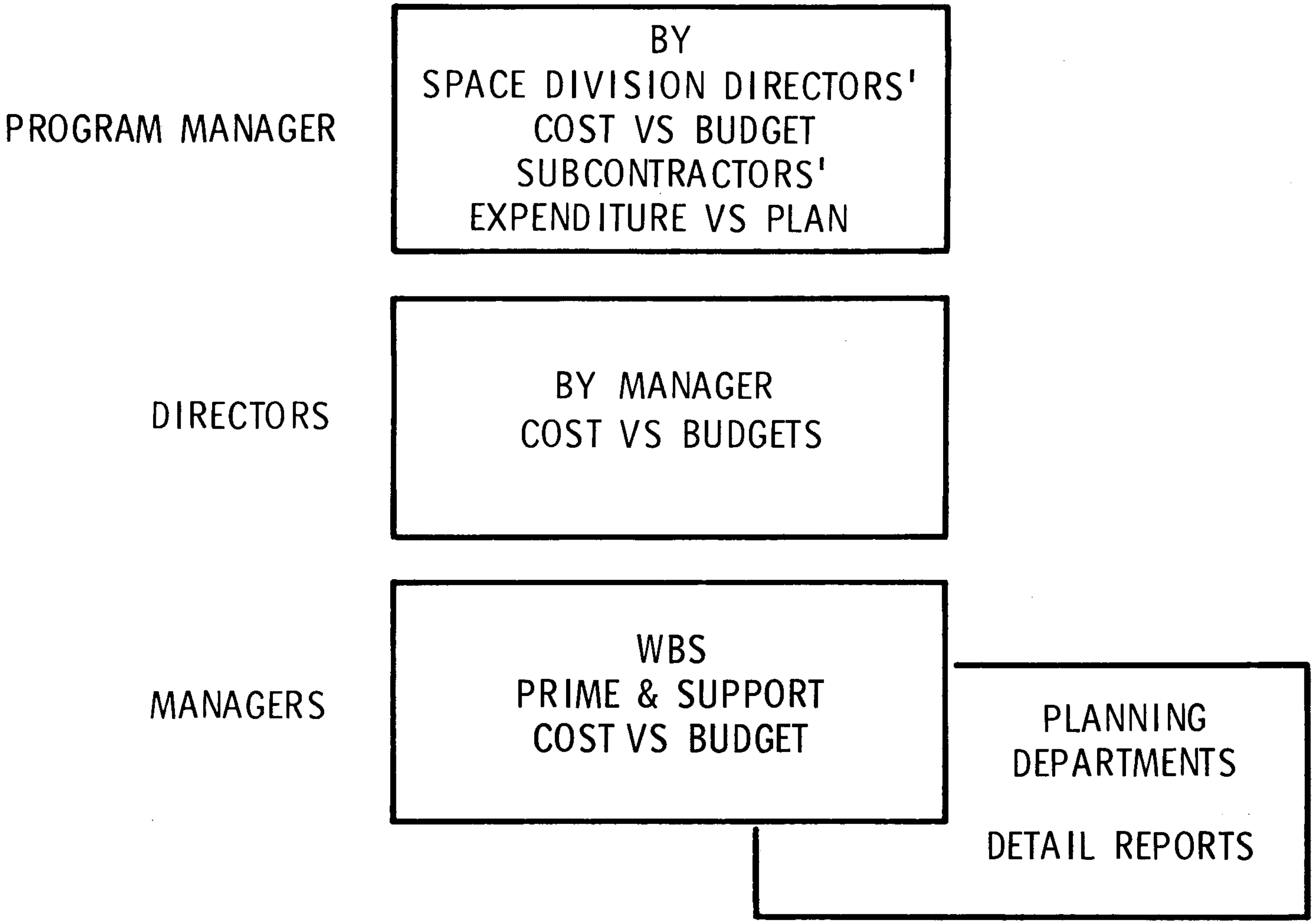


Figure 7-7. Cost Reports

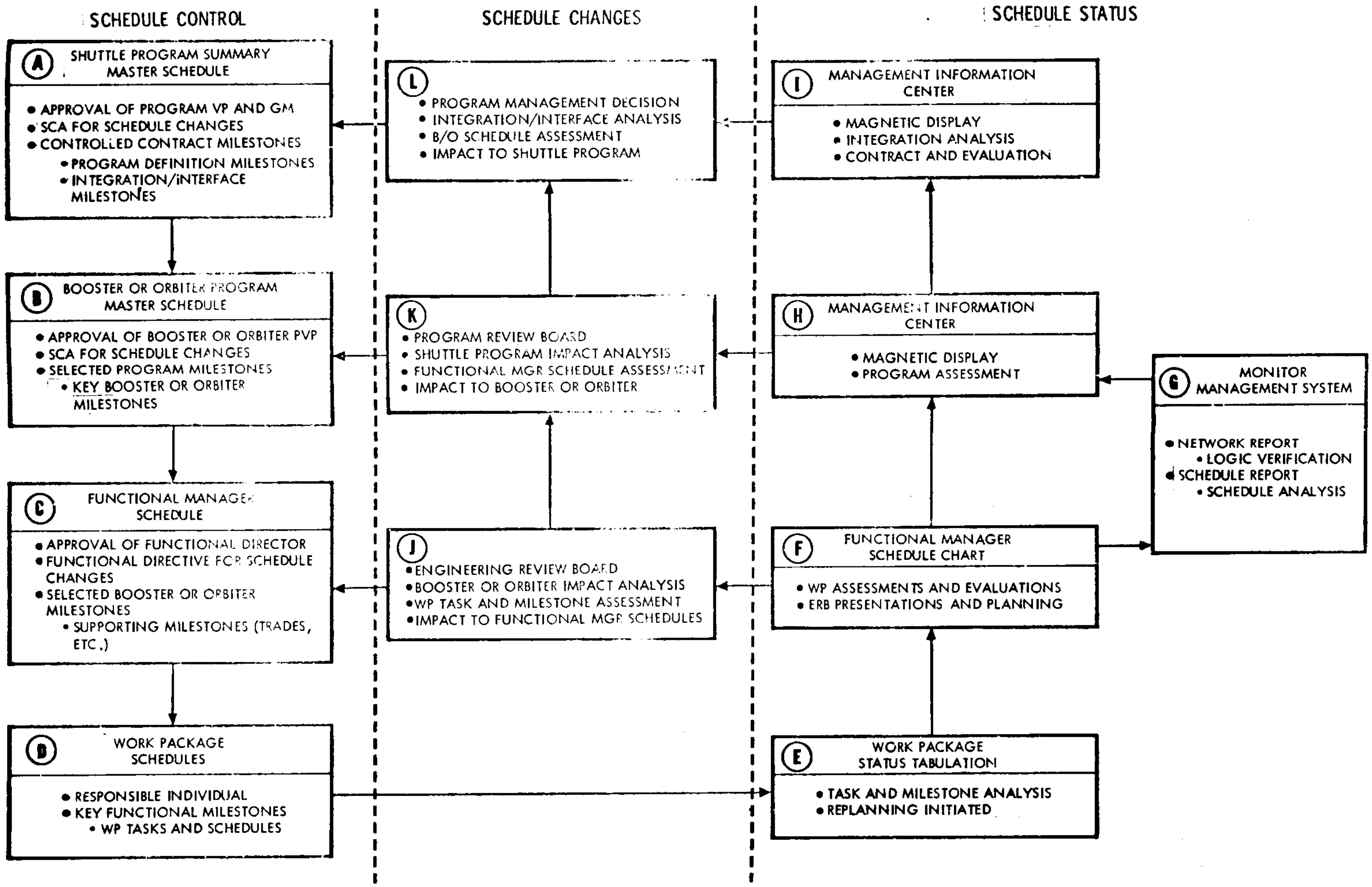


Figure 7-8. Schedule and Status Relationships

(E) The WP schedule is a working document and daily awareness of performance by the responsible individual is maintained. Update of the WP schedule data base occurs once a week and results in a schedule status tabulation of all the WP tasks and milestones. Where program level schedule milestones are affected, problem resolution is implemented and the necessary replanning initiated.

(F) The functional manager schedule chart (Figure 7-9) is statused mechanically each week from the update of the WP schedule status tabulation. The functional manager schedule chart is utilized as required for assessments and evaluations during the Program Business Review meetings. The orbiter and booster program master schedules and Shuttle Program Summary Master Schedule are statused weekly using information from the functional manager schedule charts.

(G) The functional manager schedule chart status is used as a data source for program logic verification and for developing alternative problem solutions. Figure 7-10 shows the impact of program performance on an established plan that reflects program interrelationships and constraints and uses critical path methodology. It provides management with visibility on critical planned program tasks and is a tool, among other things, used for decision-making related to selection of workable alternatives in schedule planning.

The schedule report (Figure 7-11) contains a comparison of milestone expected completion date against scheduled date. The schedule report reflects all milestones identified in the PMN (Section 5.0).

(H) Booster or orbiter program master schedules are maintained in the respective Management Information Centers (MIC) at GD and NR. These schedules are updated from the functional manager schedule chart status and utilized by the booster or orbiter PVP to conduct his status meetings.

(I) The Space Shuttle Program Summary Master Schedule is maintained in the MIC's at GD and NR. This schedule provides the VP&GM with overall visibility and is utilized for program planning and discussion at the status meetings.

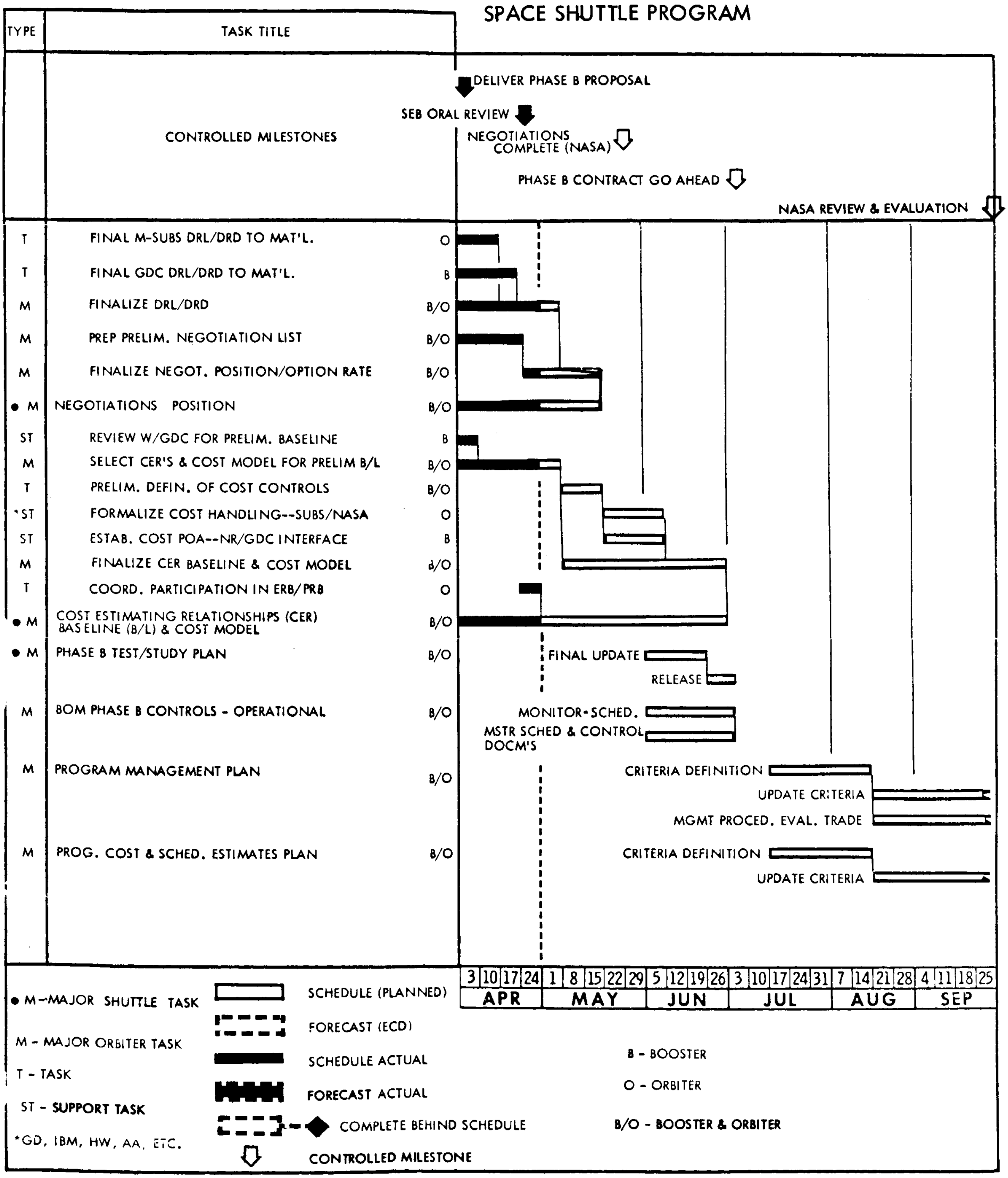


Figure 7-9. Functional Manager Schedule Chart (Example)

CRITICAL PATH

NORTH AMERICAN ROCKWELL, INC.
SPACE DIVISION

NETWORK REPORT

U310HPS4
PAGE-1

SUBNET - PROGRAM MGMT NET SPACE SHUTTLE 1
SORTED BY - PRIMARY SLACK

SSMGMT

RUN DATE 18MAR70
DATA AS OF 01JUL70
SEQ NO. 13.35

ETS	PRED. EVENT	SUCC. EVENT	ACTIVITY DESCRIPTION / WBS NUMBER LEV M I S C D A T A	S/CODE	TIME	SLACK PRIM.	SLACK SECND	**COMPLETION DATES*** EXPECTED	LATEST	SECONDARY	SCHEDULE	DEPT/ GROUP
S		1000	CONTRACT GO-AHEAD			.0		A01JUL70	01JUL70			
	1000	1008	131/231 START SUBSYSTEM DEFINITION 4.3 3		01.0	.0		08JUL70	08JUL70			
	1000	1006	12/22 START DESIGN ANALYSIS 4.2 3		01.0	.0		08JUL70	08JUL70			
	1000	1004	11/21 START SYSTEM ANALYSIS 4.1 3		01.0	.0		08JUL70	08JUL70			
	1008	1017	132/232 NASA DEF REQS M1070 COM/AVNC 4.3.2 4		04.0	.0		05AUG70	05AUG70			
	1017	1038	132/232 DIGITAL INTERFACE TECHNIQUES 4.3.2 4		01.0	.0		12AUG70	12AUG70			
	1004	1058	115/215 VEHICLE TRANSITION CONTROL 4.1.5 4		07.0	.0		26AUG70	26AUG70			
	1006	1148	123/223 INITIAL TPS DEFINED 4.2.3 4		12.0	.0		30SEP70	30SEP70			
	1017	1150	32 INITIAL SUBSYSTEM DEFINITION 4.3 3		08.0	.0		30SEP70	30SEP70			
	1038	1108	132/232 INITIAL AVIONICS SYS DEFINED 4.3.2 4		07.0	.0		30SEP70	30SEP70			
	1170	1172	CXS		00.0	.0		30SEP70	30SEP70			
	1154	1170	CXS 4.2 3		00.0	.0		30SEP70	30SEP70			

Figure 7-10. Network Report (Example)

U310RS12
NORTH AMERICAN ROCKWELL CORPORATION

SCHEDULE REPORT

CONTRACT CODE 70PR3P PAGE 5

WORK BREAKDOWN STRUCTURE SCHEDULE REPORT

REPORT DATE 01JUL70
ISSUE DATE 17MAR70

CONTRACT NUMBER AND DESCRIPTION SPACE SHUTTLE B SPACE SHUTTLE PROGRAM DEFINITION (B)

MOD	LEV *	WBS NUMBER **********	MILESTONE NUMBER *******	MILESTONE DESCRIPTION	PVWA	SCHEDULED COMPLETION DATE	EXPECTED/ACTUAL COMPLETION DATE	SCHEDULE VARIANCE
	9	2800312024	2800301	START LANDING SYSTEM DEFINITION		08JUL70	08JUL70	0.0
	9	2800312024	2800302	RECEIVE CONTROL SCHEMATIC		10JUL70	10JUL70	0.0
	9	2800312024	2800303	RECEIVE TEPERATURE ANALYSIS		31AUG70	31AUG70	0.0
PERT	9	2800312024	2800304	INITIAL LANDING SYSTEM DEFINED		30SEP70	30SEP70	0.0
	9	2800312024	2800306	START FAILURE ANALYSIS		01NOV70	01NOV70	0.0
	9	2800312024	2800305	RECEIVE LOADS AND STRESS		01NOV70	01NOV70	0.0
	9	2800312024	2800307	START HAZARD ANALYSIS		01NOV70	01NOV70	0.0
PERT	9	2800312024	2800308	UPDATED LANDING SYSTEM DEFINED		30DEC70	30DEC70	0.0

Figure 7-11. Schedule Report (Example)

(J) Schedule changes and approvals to the program schedule baseline will usually be the result of technical evaluations emanating from the ERB and PRB decisions. The schedule change request (SCR) and schedule change authorization (SCA) process is utilized when it has been determined that a program milestone will be impacted by pursuing the current WP planning. An SCR is processed requesting a change to the affected milestones schedule dates. This is submitted to program management along with the description of the replanning required to support the proposed schedule change.

(K) When functional level management assess that the booster or orbiter program master schedules are impacted. workable alternative plans are presented with an SCR. An approved SCA is released to revised the respective orbiter or booster program master schedule and subordinate schedules.

(L) When the booster or orbiter PVP assesses that the program status position imperils the Space Shuttle Program Summary Master Schedule, workable alternative plans are presented with an SCR. If an analysis indicates that the impact does not revise a contract requirement, an SCA is released to revise all lower level program schedule planning.

7.2.3 Status Meetings

Weekly status meetings are held in the Shuttle Management Information Center (MIC) and cover three main topics — schedule, cost, and technology. The resource information is presented and reviewed at the director level. Each director responds to specific questions on progress or variances taking schedule relationship into consideration. If there is a variance or problem, the director identifies which WBS or task within the WBS is impacting. Action items are assigned by the Program Manager. Figure 7-12 depicts the weekly meeting subjects. The schedule part of the presentation consists of a review of significant program milestones and status. The Shuttle Program Summary Master Schedule, displayed in the MIC, is the focal point of the presentation. Management visibility is extended into the orbiter and booster program master schedules and functional manager schedules, as required, to provide greater detail of significant status and/or problem identification. The top 5 to 10 program problems and assigned actions are selected during the review. Minutes of each meeting are taken and distributed to attendees and action assignees. Summaries of the weekly meeting and photographic reproductions of the MIC schedule are utilized to compile the monthly progress and status reports to NASA.

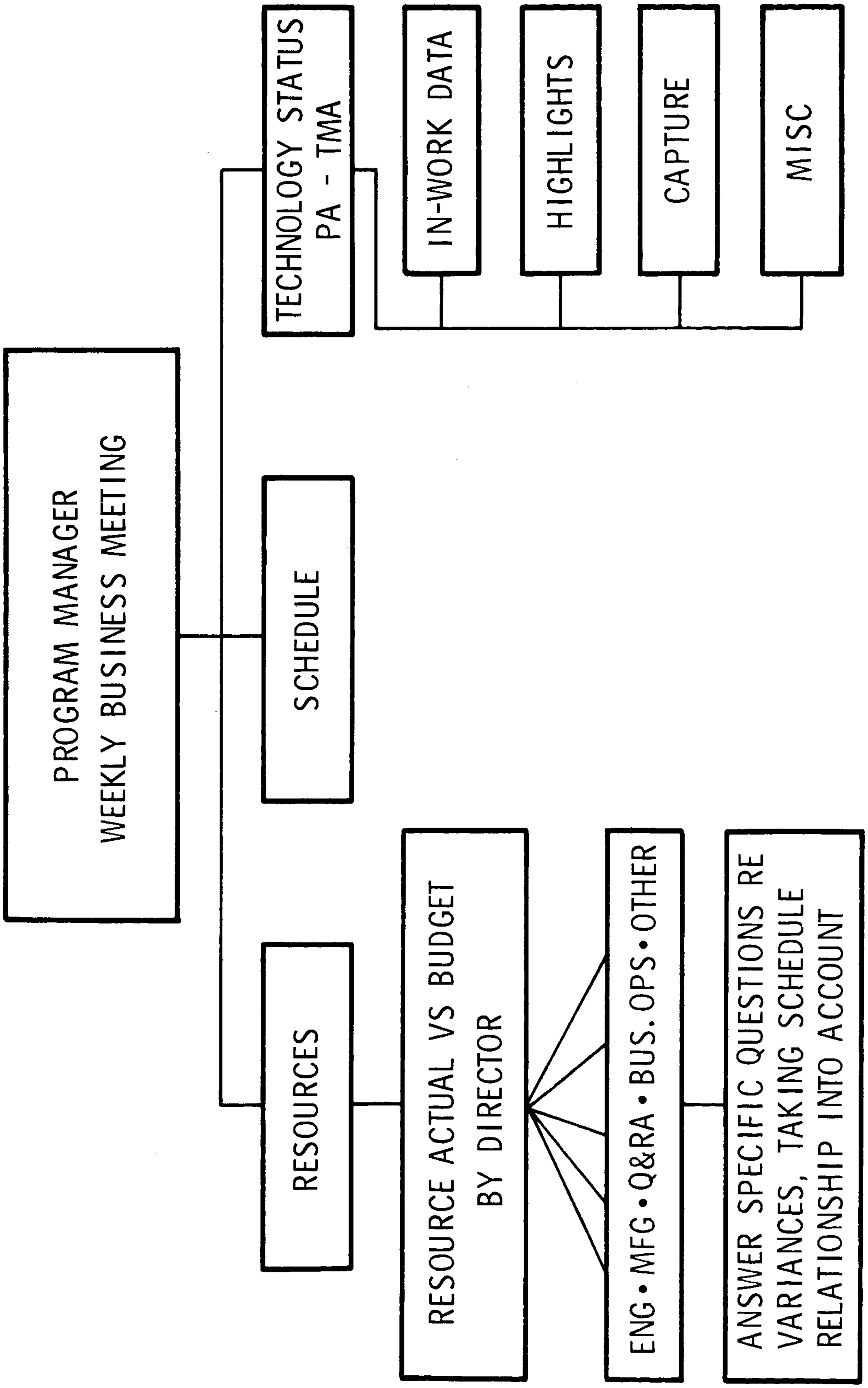


Figure 7-12. Weekly Status

7.3 VARIANCE ANALYSIS AND CORRECTIVE ACTIONS

Assessments and evaluations of critical schedule variances are made at the functional manager schedule level. It is from this point that program status and impact problems are introduced to program management for approval of proposed replanning or program management redirection. The schedule variances are identified and ranked in order of their effect on program schedules. Workable alternative solutions to regain an acceptable program position are submitted, and an optimum method is recommended on the basis of detailed analysis of technical, schedule, and budgetary considerations. Coordination of alternative solutions to program/schedule variances is accomplished with responsible functional management prior to approval by program management. Corrective actions include consideration of the use of premium time, shifting resources, rephasing subsequent tasks to accommodate the accomplishments of critical milestones, and rescheduling portions of the program to maintain overall schedule integrity. A program directive authorizes required changes to budgets, technical tasks, and schedules. The specific approved schedule revisions are released by the program directive and a supporting SCA.

7.4 CUSTOMER REPORTING IN ACCORDANCE WITH DRD MA020M

In response to requirements of MA020M, a monthly Space Shuttle Program Progress and Status Report will be submitted. The report will encompass a 30-day period and will be submitted within 15 days following the cutoff date; The initial submittal to be within 45 days after contract go-ahead. The enclosed format (Example A) is prepared to the following outline:

A. Transmittal Letter

B. Report Content

Introduction

I. Program Management Highlights

II. Accomplishments - Planned Versus Actual Milestones

Activities - By WBS/PERT identification

Estimated Versus actual dates

On-behind-ahead of schedule identification, slack, days of slippage

Description of activity change

III. Planned Effort

Same content as II, except for next two months

IV. Significant Problems

List of 5 to 10 most significant problems — in order of importance

Description of problem and corrective action being taken

V. Illustrations

Shuttle Program Summary Master Schedule

(Photo reproduction of Magnetic displays in Management Information Center)

Example A
Page 1

TRANSMITTAL LETTER

August 14, 1970 70MAXXXX

Contract NASX-XXX, Transmittal of the Space Shuttle Monthly Progress and Status Report

The enclosed Monthly Progress and Status Report for the month of July 1970 is furnished in accordance with Contract NASX-XXX.

NORTH AMERICAN ROCKWELL CORPORATION

B. Hello
Vice President and General Manager
Space Shuttle Program
Space Division

Enc. Space Shuttle Monthly Progress and Status Report

cc: NASA required distribution

Space Shuttle Program
Monthly Progress Report for July 1970

INTRODUCTION

Progress achieved during the month of July 1970 in support of the Space Shuttle Program, Contract NASX-XXX, is summarized in this report according to contract requirements. Significant problems are identified and their actual or proposed resolutions are noted.

I. PROGRAM MANAGEMENT

Highlights

The following studies progressed as planned during July ... etc.

II. ACCOMPLISHMENTS — PLANNED VERSUS ACTUAL

Item	PMN Activities	Exp/Act	On Sched	Slack (weeks)	Days of Slippage	Remarks
A	0000 - 1000	A 01 Jul 70	Yes	0.0	0	None
B	1000 - 1008	A 12 Jul 70	No	0.8	4	Late subsystem definition

Discussion:

Item A was completed ahead of schedule.
Item B was completed four days late to schedule due to ... etc.

Example A
Page 3

III. PLANNED EFFORT

Item	PMN Activities	Exp/Act	On Sched	Slack (Weeks)	Days of Slippage	Remarks
C	1008 - 1017	05 Aug 70	No	0.6	3	NASA has TWX advising of delay in definition and requirements.
D	1017 - 1038	12 Aug 70	No	0.2	1	Two days of late definition and requirement will be recovered.

Discussion:

Item C (digital interface techniques) is expected to be delayed ...

IV. SIGNIFICANT PROBLEMS

SHUTTLE PROGRAM PROBLEM SUMMARY

Problem No.	Function	Description	Date	Corrective Action	Exp Completion Date ECD	Responsible Manager
1	Eng	Digital Interface Techniques	1 Aug 70	Replan Tasks	8 Aug 70	Anderson

(Reproduction of Chart to be maintained in MIC)

V. ILLUSTRATIONS

(See Figure 7-13.)

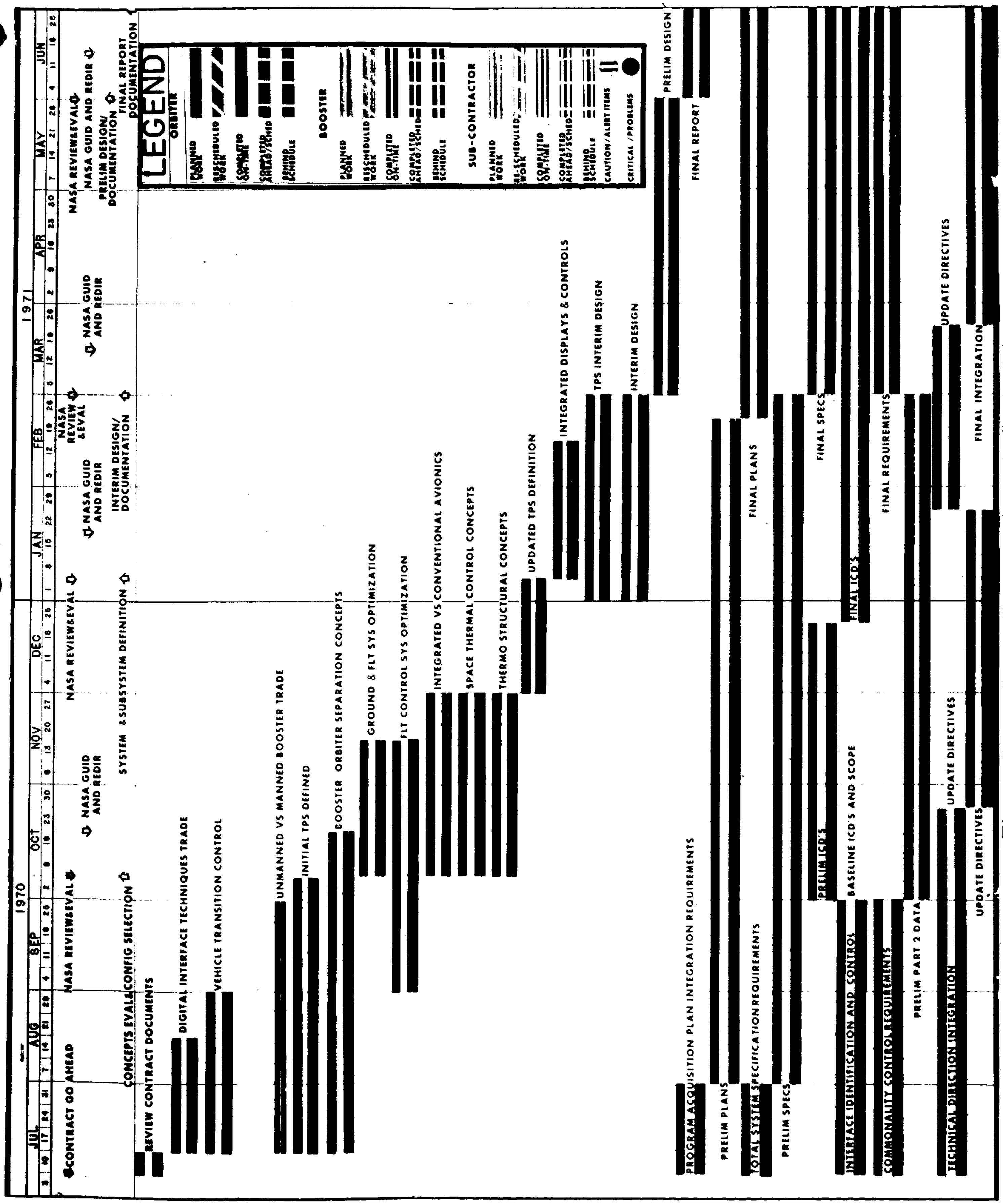


Figure 7-13. Space Shuttle Phase B Study Schedule